GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Sports Nutrition Part 1

Dr. James Meschino DC, MS, ROHP

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Sports Nutrition: What Can it Do?

Studies Show That Targeted Nutritional Strategies Significantly Enhance Exercise Performance in Three Important Ways:

1. Complements Daily Training Routine by Enhancing:

- Lean Mass Gains
- Explosive Power
- Recovery
- Endurance and Speed Endurance
- Immune Competence
- And Decreases Muscle Damage and Inflammation

2. Extends Years of Competitive Participation

- Preventing Muscle Catabolism
- Diminished Energy
- Body Fat Changes
- Inflammation
- Joint Cartilage Damage
- Preservation of Brain Function

3. Enhances Performance on Game Day or Tournament Days:

Reference Texts for this Subject

1. Sports and Exercise Nutrition (fourth edition)- Required Textbook

- William D. McArdle
- Frank I. Katch
- Victor L. Katch
- Wolters Kluwer/Lippincott & Wilkins (2013)

2. Exercise Physiology: Energy, Nutrition and Human Performance (second edition)

- William D. McArdle
- Frank I. Katch
- Victor L. Katch
- Lea & Febiger (1986)

3. Physiology of Exercise: Responses & Adaptations (second edition)

- David R. Lamb
- MacMillan Publishing Company (1984)

4. Essentials of Strength Training and Conditioning: National Strength and Conditioning Association

- Thomas R. Baechle (Editor)
- Human Kinetics (1994)

Also see Additional Research Review Papers in Course Materials

GLOBAL INTEGRATIVE MEDICINE ACADEMY

Major Topics Covered in this Subject (Section)

Subsection: 1: Key Factors in Exercise Physiology

- Functional Muscle Anatomy, Physiology and Exercise Adaptations Review
- Strength-to-Mass Ratio
- Interval Training
- Energy Systems
- Aerobic Training Zone
- Substrate Utilization At Various Exercise Intensity and Duration
- Adaptations to Aerobic Exercise – Peripheral and Central
- Lactate Levels and recovery during Interval Training
- Lactate Physiology – Cori Cycle

GLOBAL INTEGRATIVE MEDICINE ACADEMY

Subsection 2: Macronutrients and Nutrient Utilization

Carbohydrates and Athletic Performance

- CHO Loading vs Ketogenic Diet in Performance Outcomes
- Day -to Day CHO Intake
- CHO Ingestion Pre-competition
- CHO Ingestion Immediately Prior to Competition
- CHO During competition – sports drinks
- CHO Post competition
- Tournament Day Nutritional Strategies

Protein Requirements – Updated Protein Requirements for athletes gm/kg (dose, timing, quality)

- Glutamine and Alanine Physiology During Exercise
- Leucine and Branched-chain Amino Acid Research

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Fat Intake and Body Fat Percentage:

Fat Intake, Metabolism and Body Fat

Basal Metabolic Rate, METs and Individual Caloric Needs

Diet Composition for Different Types of Athletes (Endurance, Mixed and Body Builder)

Overall Nutritional Strategies Relative to Timing of Competition/Training

- Day-to-Day Nutrition Strategy
- Pre-competition Meal
- Nutritional Intake 30 mins Prior to Competition/Training
- Nutritional Needs During Events Lasting More than 40 mins
- Post Competition Nutritional Intake
- Tournament Day/Competition Nutritional Strategies

In Sports Nutrition Part 2 we will complete the Sports Nutrition Story by Examining:

A. Methods of Body Heat Dissipation

B. Hyperthermia/Hypothermia

C. Fluid and Electrolyte Requirements

D. Ideal Sports Drink Composition

E. Effects of Clothing and Climate on Heat Dissipation and Dehydration

G. Assessing Ambient Temperature and Risk Level of Exercise in the Heat

H. Ergogenic Aids – specific dietary supplements shown to enhance athletic performance, lean mass gains, explosive power, recovery, reduce body fat, and support immune function in athletes

Less than 25% of the population gets enough exercise to reduce risk of vascular and other problems

Subsection 1: Functional Muscle Anatomy and Physiology

- Muscle Fiber – size of human hair
- Muscle Bundle – (fasciculi) – 150 muscle fibers
- Cytoplasm – protein contractile elements (myofibrils), comprised of myofilaments (actin and myosin protein)
- There are hundreds of myofibrils in each muscle fiber – hypertrophy results in increased number of myofibrils

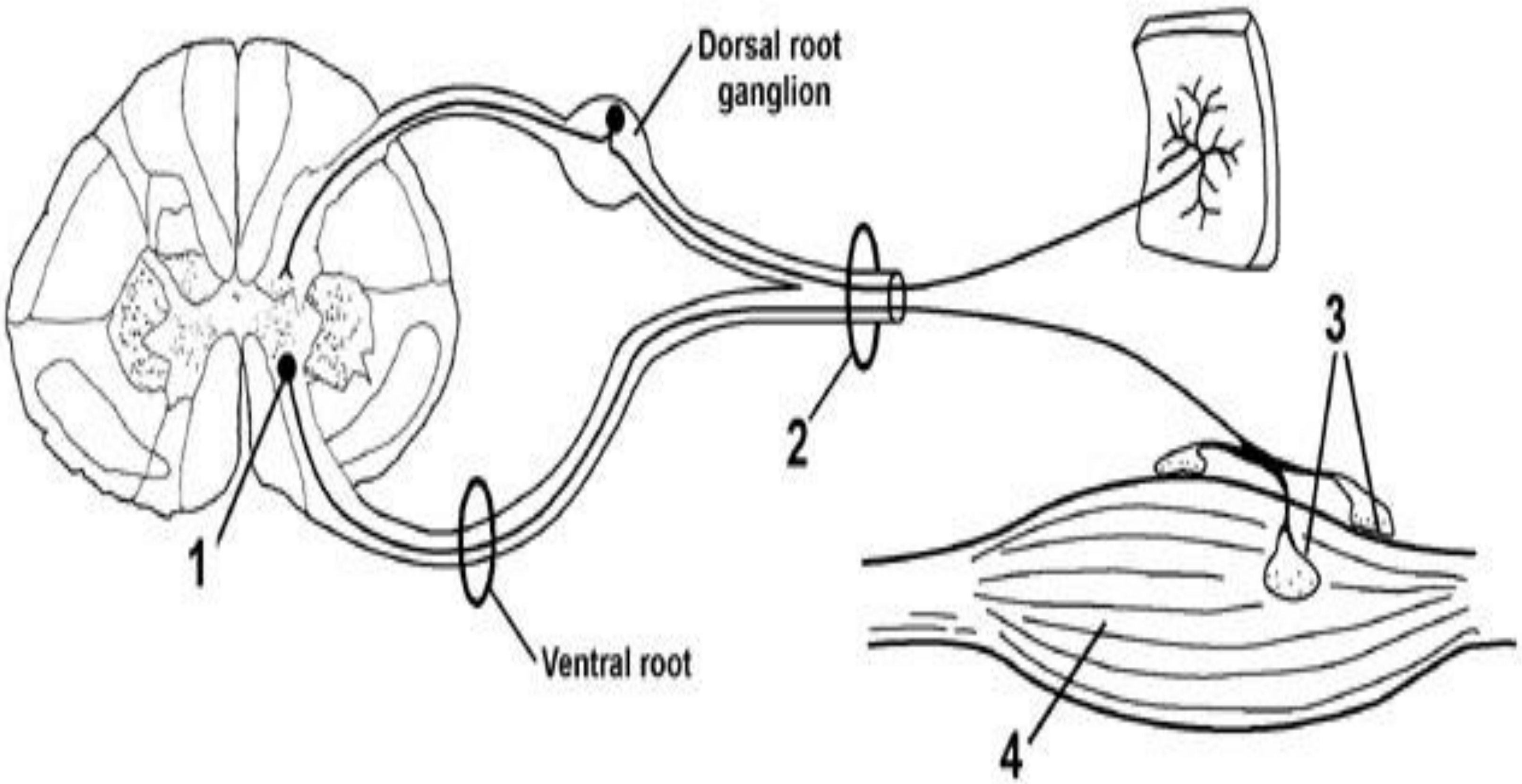
- Motor Unit – lower motor neuron and all innervated muscle fibers (of same type) – fast or slow twitch

- Slow Twitch Fibers (type 1) – slow force development, highly aerobic, fatigue resistant, recruited first in contraction

- Fast Twitch Fibers (type 2) – fast force development, highly anaerobic, easily fatigued, requires greater neural stimulation

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Motor Unit



GLOBAL
INTEGRATIVE MEDICINE ACADEMY

- Postural Muscles – mostly slow twitch (don't fatigue easily)

- Locomotor Muscles – mixture of fast and slow twitch m., with wide genetic variation between individuals and between muscle groups within the same individual.

- This accounts for a major edge in many sports (e.g. explosive athletes may have 80 – 90% fast twitch m. fibers, whereas superior endurance athletes may have 80 –90% slow twitch m. fibers (Speed Rules In Many Sports)

- Muscle Strength Gains with Resistance Training:
  - First 1–2 months – increased neural recruitment
  - Post 2 months – mostly hypertrophy (limited by total no. of m. fibers. Therefore, some athletes have a genetic edge)

- Fast Twitch m. Fibers respond to moderate to heavy training (4-8 repetitions to failure) – allows strength and <u>*power*</u> gains

- Slow Twitch m. Fibers respond to high volume training with short rest interval if hypertrophy is the goal (e.g., body builder style of training – forced glycolytic metabolism of type I m fiber

- **Strength To Mass Ratio** – gaining mass at greater rate than gaining power (mass x distance/time) slows an athlete down, compromising performance in speed and acceleration

- Thus, Body Builder training style can be counter-productive to athletic performance. This is why functional training has become so popular and increases performance for various types of athletes

- Intermediate Muscle Fibers – respond to type of training performed (endurance athletes have poor vertical jump)

- **Interval Training** – permits strengthening of aerobic capacity, while encouraging anaerobic power adaptations of fast and intermediate m. fibers

- Interval Training Improves Two Important Performance Outcomes:
  - 1. Speed Endurance – maintain max speed for optimal time
  - 2. Repeated Speed Bursts – (e.g., hockey shift in third period, soccer, lacrosse, basketball, tennis etc.)

- Many sports require repeated sprint intervals, thus submax endurance training alone is inappropriate and slows the athlete down

Energy Systems: ATP-CP Energy System: Primary Energy System In Sprint Events lasting from 0-6 secs

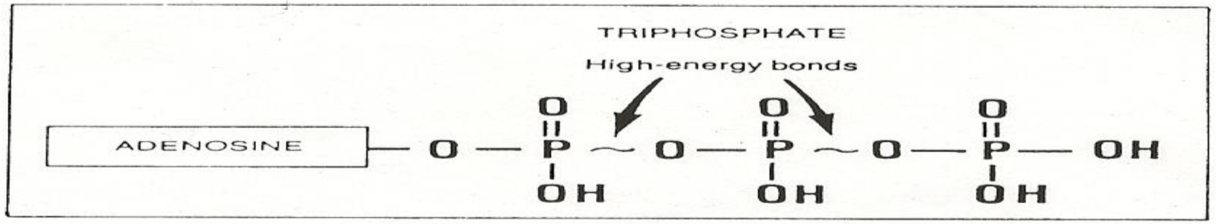


Figure 3-1. *Simplified structure of ATP, the energy currency of the cell. The symbol ~ represents the high-energy bonds.*

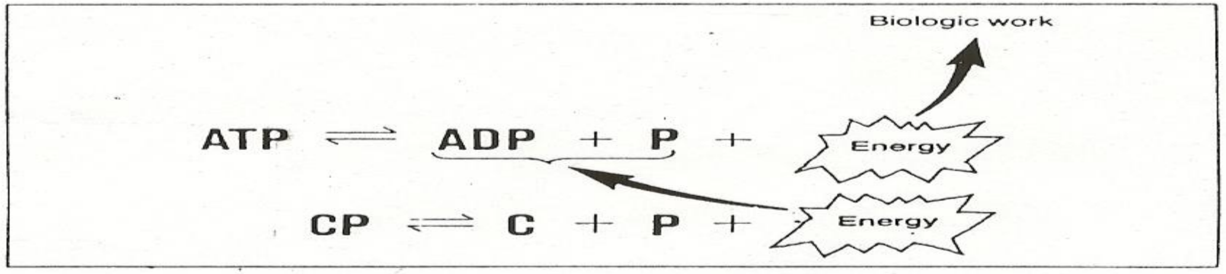


Figure 3-3. *ATP and CP are anaerobic sources of phosphate bond energy. The energy from the breakdown of CP is used to rebond ADP and P to form ATP.*

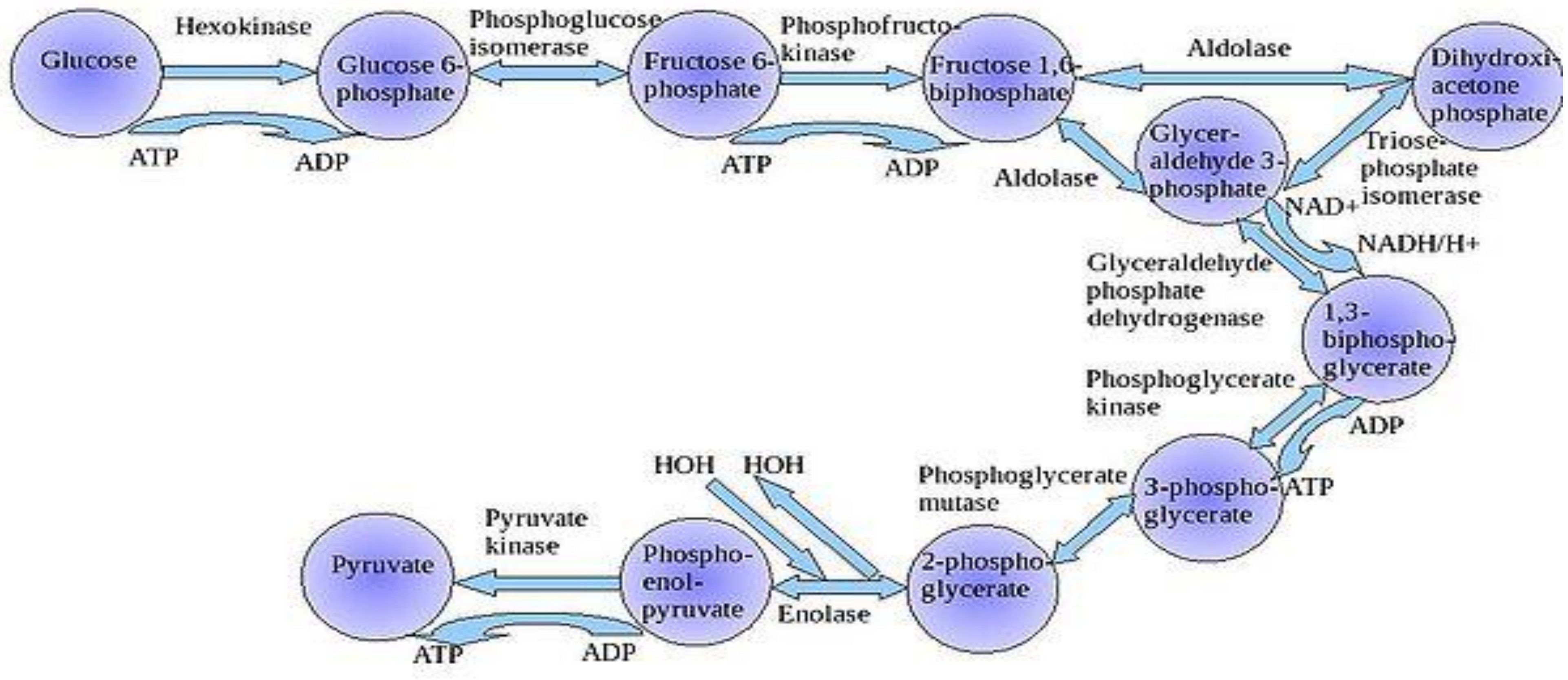
- Body stores only 3oz ATP at one time

- Cells store 4-6 times more Creatine Phosphate as ATP-supplying back up ATP energy for of all-out intensity. (ATP plus CP = max 5-8 seconds), then glycolysis re-synthesizes ATP but at slower rate than hydrolysis of CP. Hydrolysis of CP occurs via enzymatic control by creatine phosphokinase

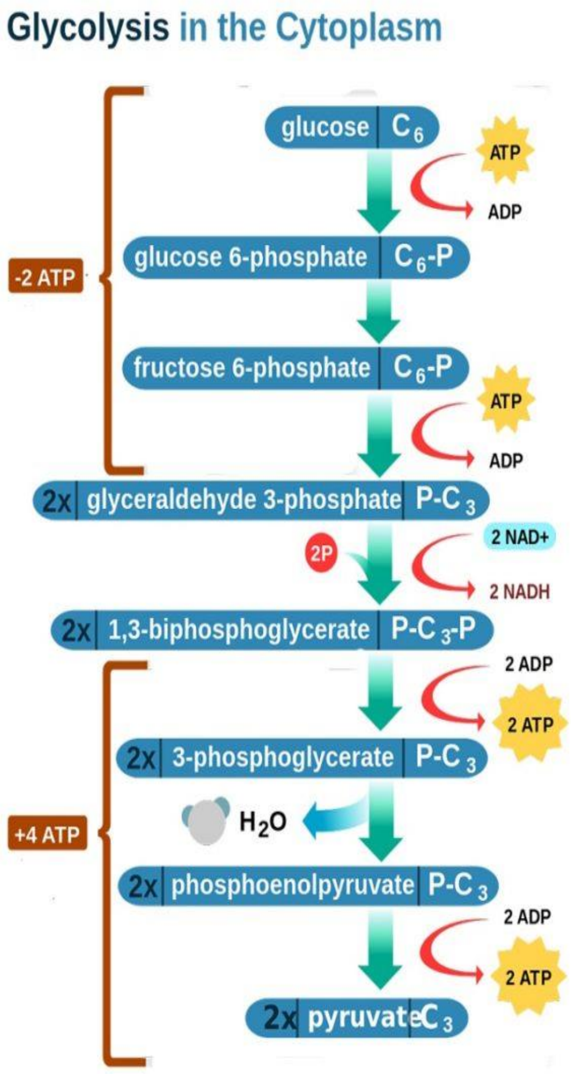
- Exercise training itself increases muscles' quantity of high-energy phosphates (ATP plus CP). Best way to increase these stores is with 6-10 second intervals of maximal exercise in specific activity requiring improved power-output capacity from this energy transfer system. (repeated 6-10 sec max bursts, interspersed with submax recovery)

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Fast Glycolysis: Primary Fuel In Short Sprint Events Lasting From 6 secs – 2 mins (up to 3mins)



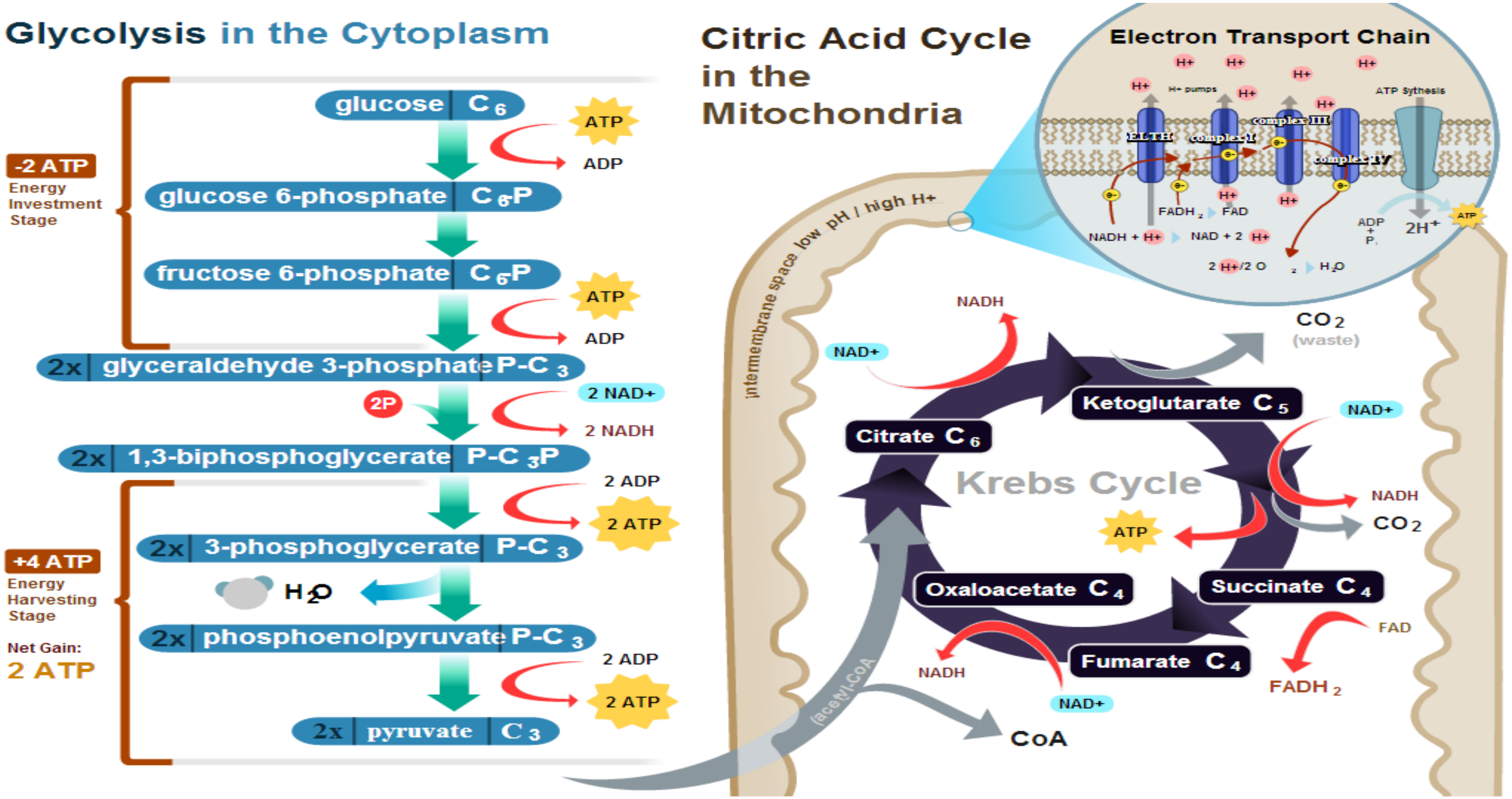
GLOBAL
INTEGRATIVE MEDICINE ACADEMY



Glycolysis accounts for 5% of total ATP energy generated from glucose breakdown, but can occur quickly (faster than aerobic metabolism) during sprint-like activity. Fast glycolysis is very inefficient and generates a great deal of heat to be dissipated. It also generates a great deal of lactic acid. High levels of acidity impair muscle performance. With training athletes are able to tolerate higher levels of intracellular and blood lactate levels with less compromised performance.

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Pyruvate converted to Acetyl CoA to Enter Citric Acid Cycle for Aerobic ATP Production



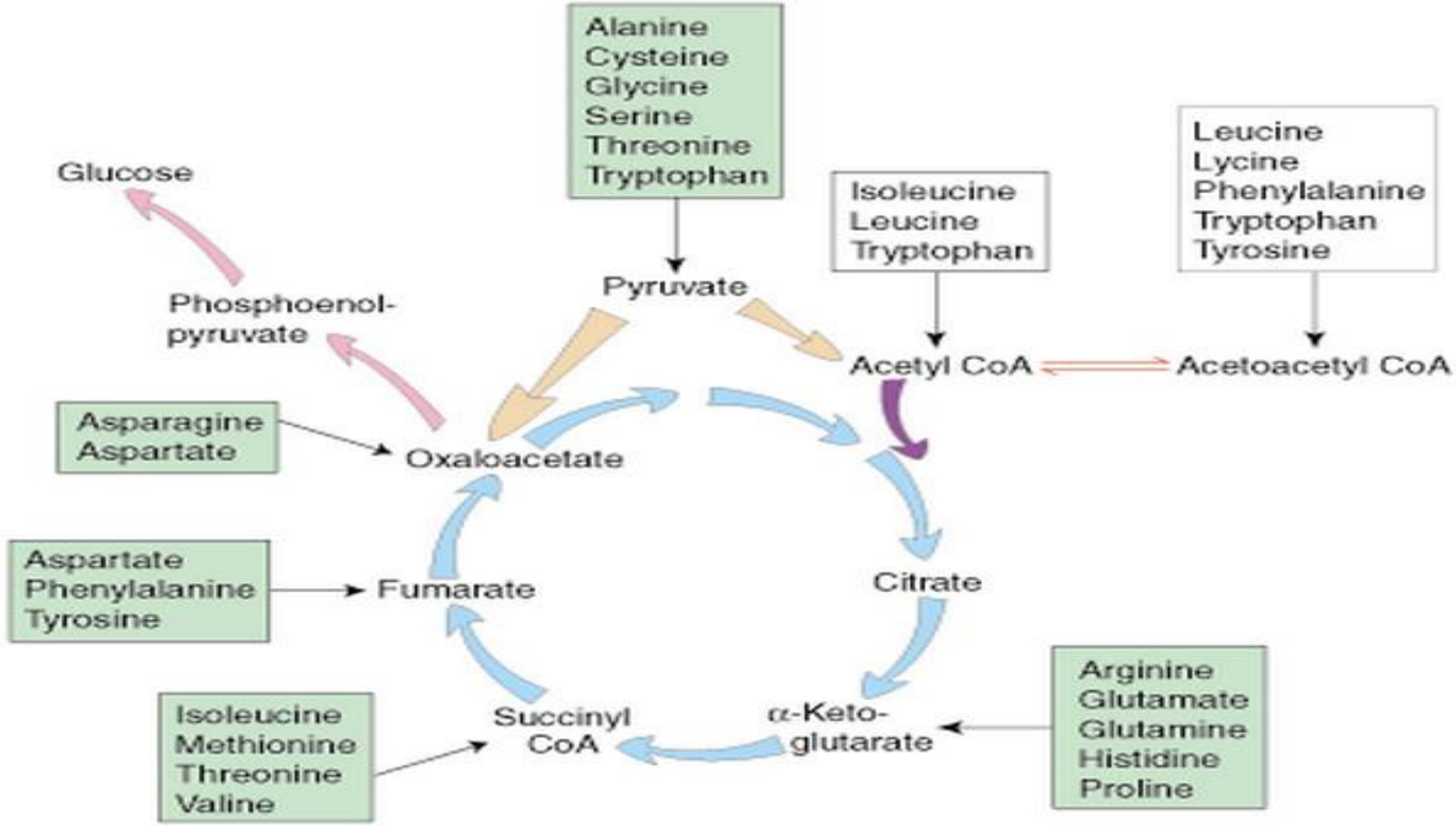
GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Efficiency of Aerobic Metabolism – generates a great amount of heat that must be dissipated to prevent hyperthermia (life-threatening)

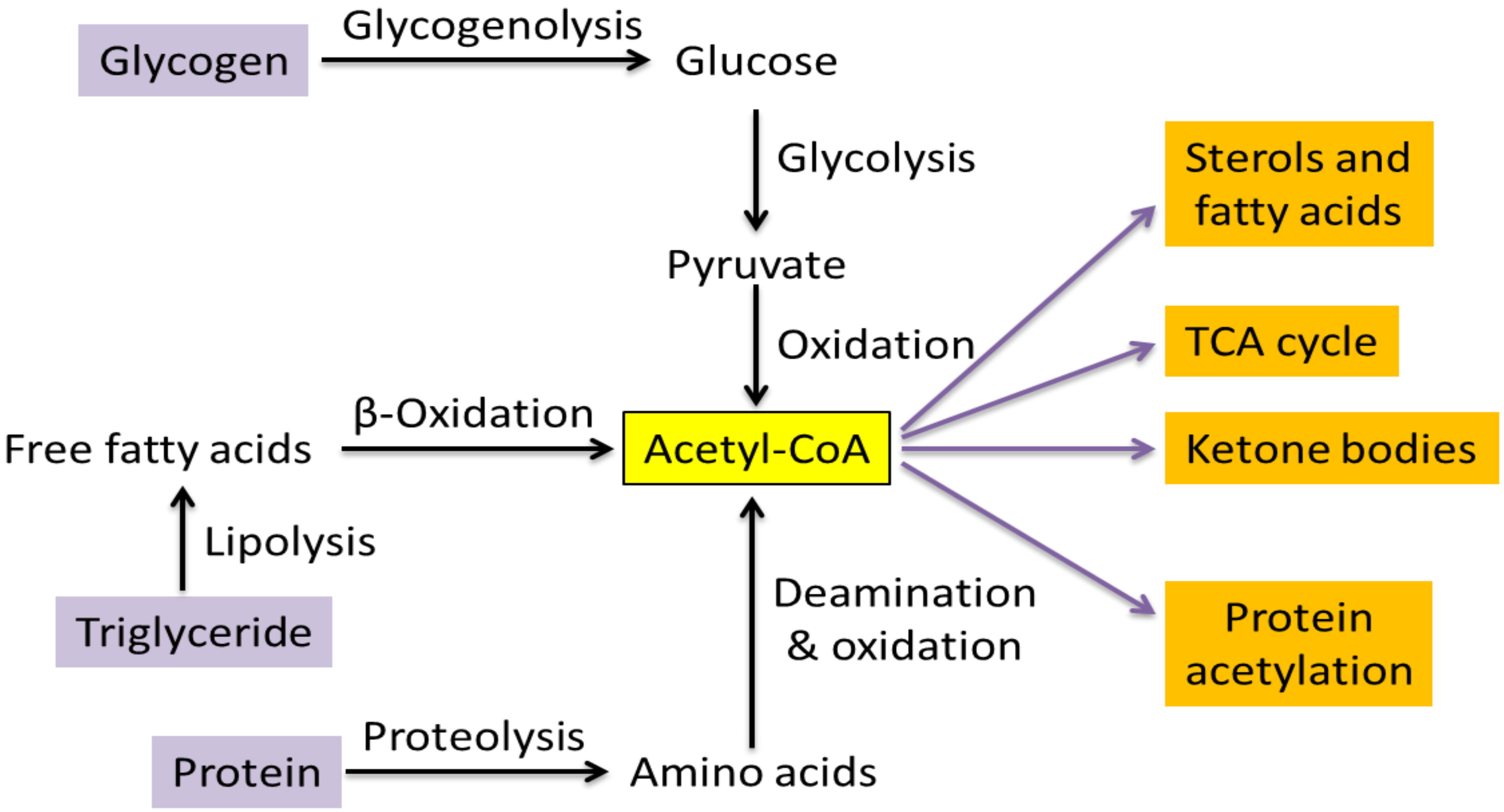
- The efficiency of oxidative phosphorylation is 34%, as such, 66% of energy dissipates as heat.
- Steam engine is about 30% efficiency, with 70% of potential energy lost as heat.

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Some Amino Acids Can Also Be Used For Aerobic ATP Production Including BCAA in Skeletal Muscle



Free Fatty Acids Arriving From Fat Cells Can Also Be Converted to Acetyl CoA for Aerobic ATP Production



GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Glycerol, Fatty Acids and Ketones

After liver glycogen reserves exhausted, glucose can be obtained from glycerol in the breakdown of fats. Fats from adipose tissue are broken down into glycerol and free fatty acids. Glycerol can be picked up by liver and used as a substrate for gluconeogenesis, to produce glucose.

So, during fasting or glycogen depleted state blood glucose is partially maintained by gluconeogenesis from glycerol, as well as, alanine, glutamine, and oxaloacetate (oxaloacetate back peddles to become glucose)

As oxaloacetate gets used up in gluconeogenesis, acetyl-CoA cannot form citrate and thus liver's acetyl-Co A (formed from beta-oxidation of fatty acids arriving from adipose tissue) is converted into ketones (water-soluble for of fat). Once in peripheral tissues ketones are converted back to acetyl-CoA and oxidized to produce ATP

- Ketones are formed in the liver from the break down of fatty acids to acetyl-Co A (the fatty acids usually arrive in the liver from adipose tissue during a fasting or low carbohydrate intake state). Once formed, ketones are taken up by many peripheral tissue (especially brain, kidneys and muscle tissue) and converted back to acetyl-CoA for oxidative phosphorylation and ATP production.

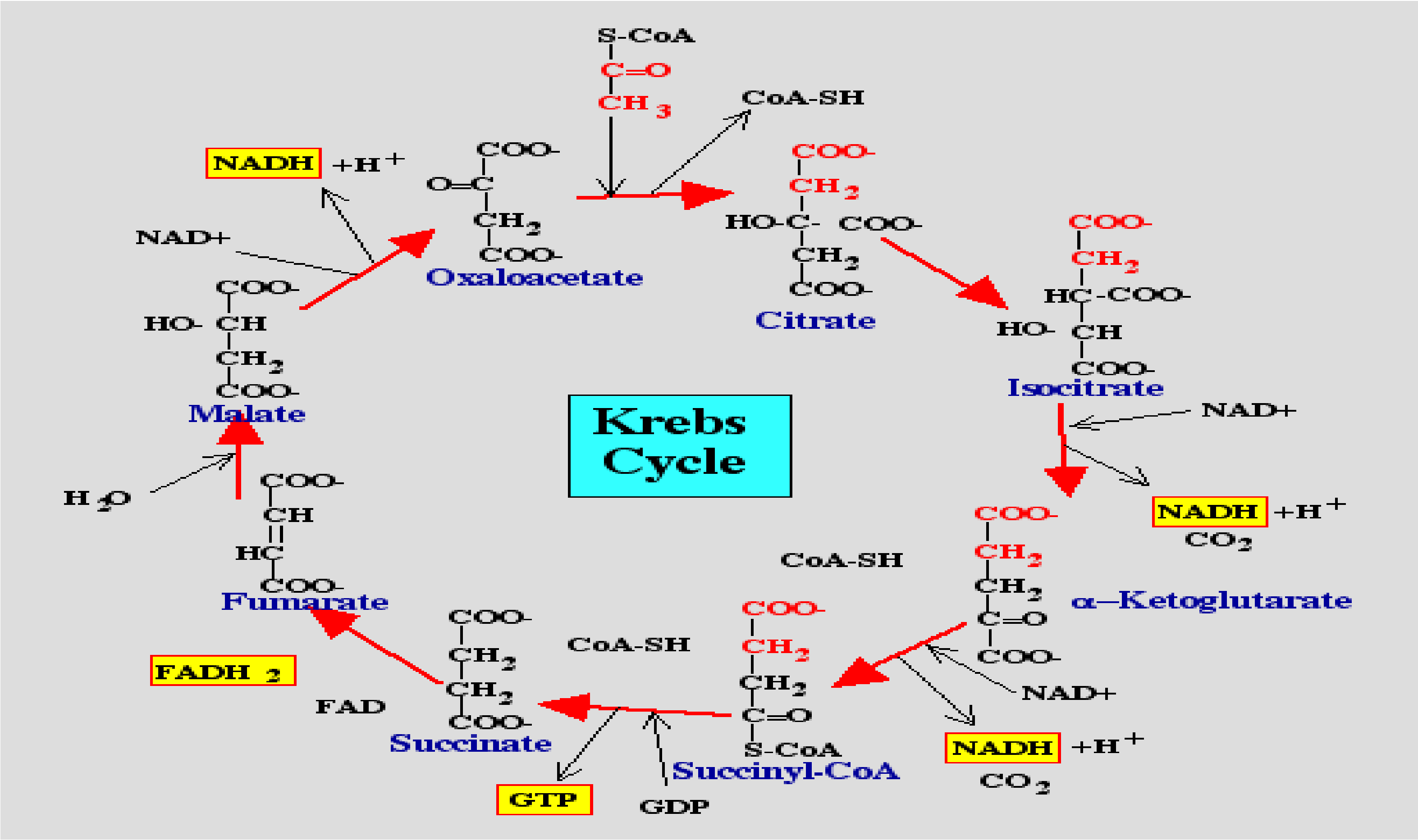
- After an overnight fast ketones contribute 10% of energy used by muscle.

- After 3-7 days of starvation ketones contribute 50-80% of all energy generated by muscles.

- The brain uses ketones as fuel, thus cutting its requirement for glucose. After fasting for 3 days, the brain gets 30% of its energy from ketones. After 4 days, this goes up to 70%.

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

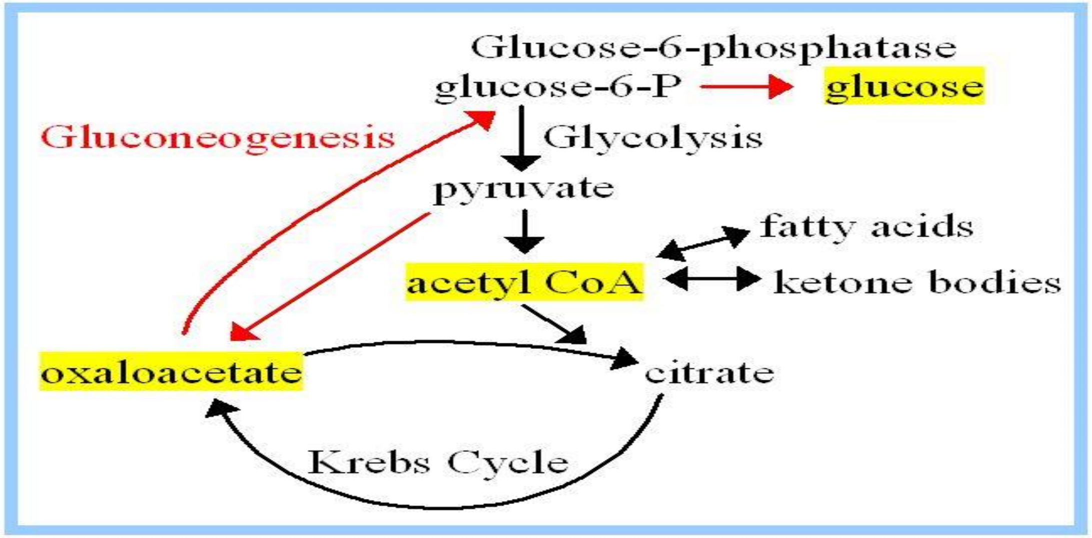
Note Oxaloacetate not available to bind with Acetyl-CoA if Glycogen Depleted (or fasting or uncontrolled diabetic) State, as Oxaloacetate back peddles to form glucose via gluconeogenesis.



Oxaloacetate Back Peddles to Glucose in Glycogen Depleted State

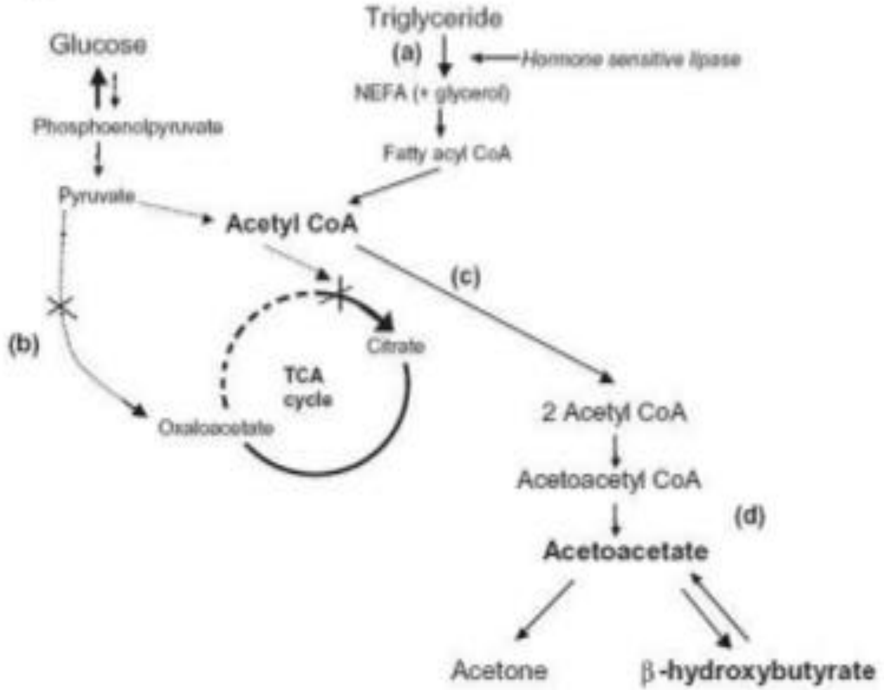
Pyruvate Carboxylase (pyruvate → oxaloactate) is allosterically **activated by acetyl CoA**.

[Oxaloacetate] tends to be limiting for Krebs cycle.



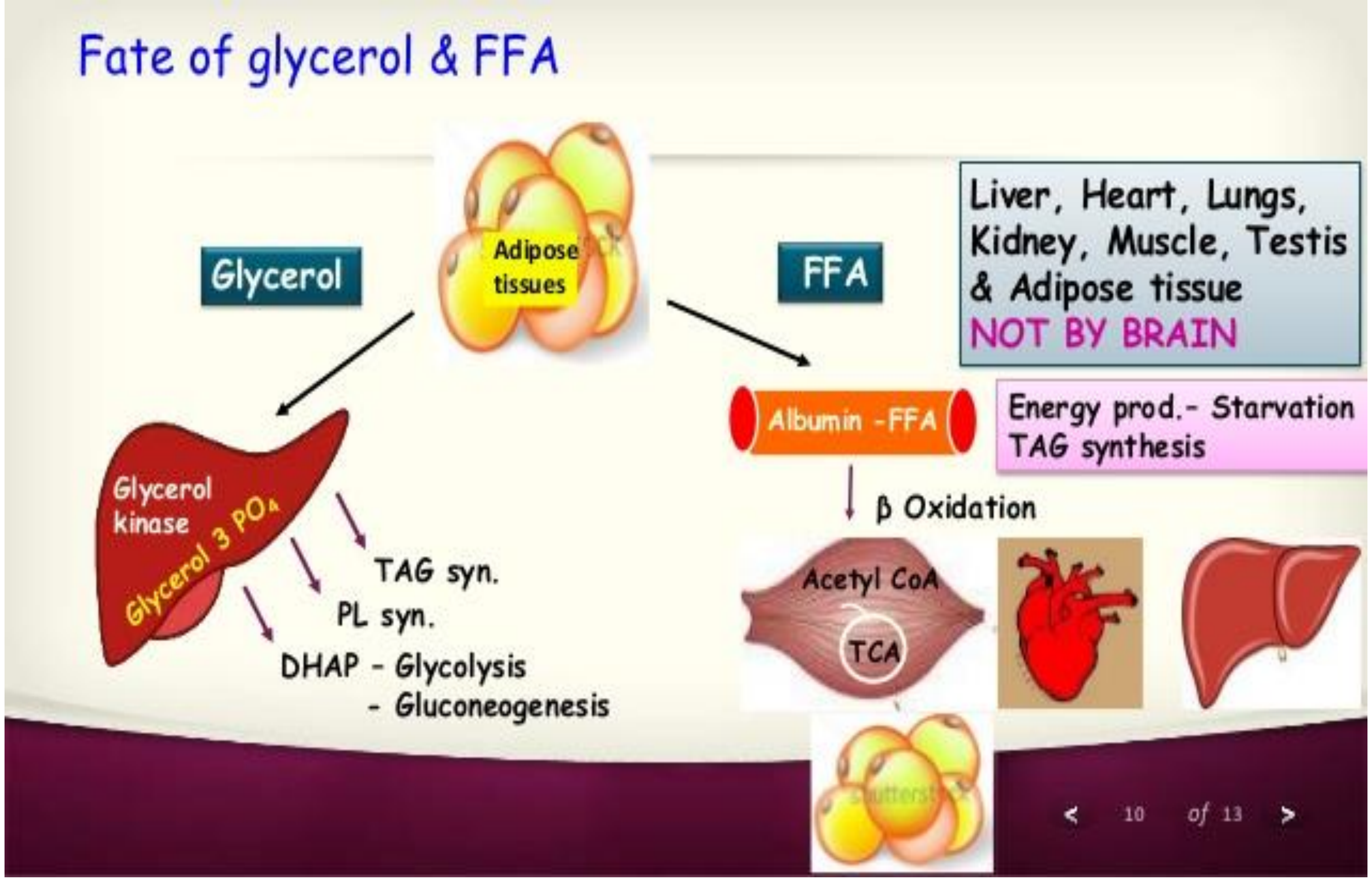
When gluconeogenesis is active in liver, oxaloacetate is diverted to form glucose. Oxaloacetate depletion hinders acetyl CoA entry into Krebs Cycle. The increase in [acetyl CoA] activates Pyruvate Carboxylase to make oxaloacetate.

Regulation of Ketosis- Overview



During high rates of fatty acid oxidation, primarily in the liver, large amounts of acetyl-Co A are generated. These exceed the capacity of the TCA cycle, and one result is the synthesis of ketone bodies.

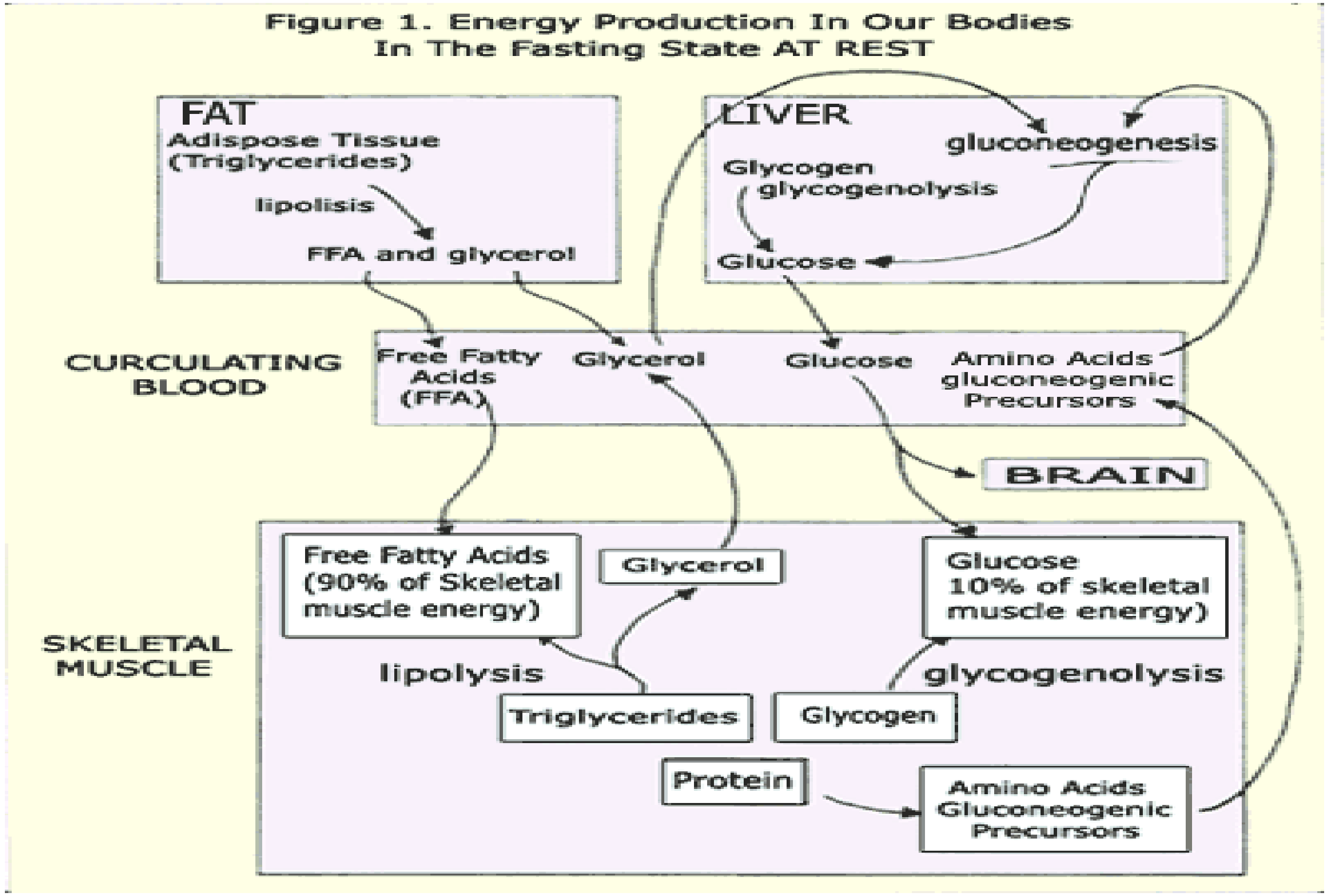
Fate of Glycerol and Free Fatty Acids



- **Fate of free fatty acids –**
- Carried by Albumin
- Taken by Muscle or Adipocytes,
- Oxidized to produce energy

- **Fate of glycerol –**
- Taken by liver to produce glycerol 3-phosphate
- Which enters Gluconeogenesis / Glycolysis or used for TAG / PL synthesis in liver.

Energy Production in Fasting State at Rest



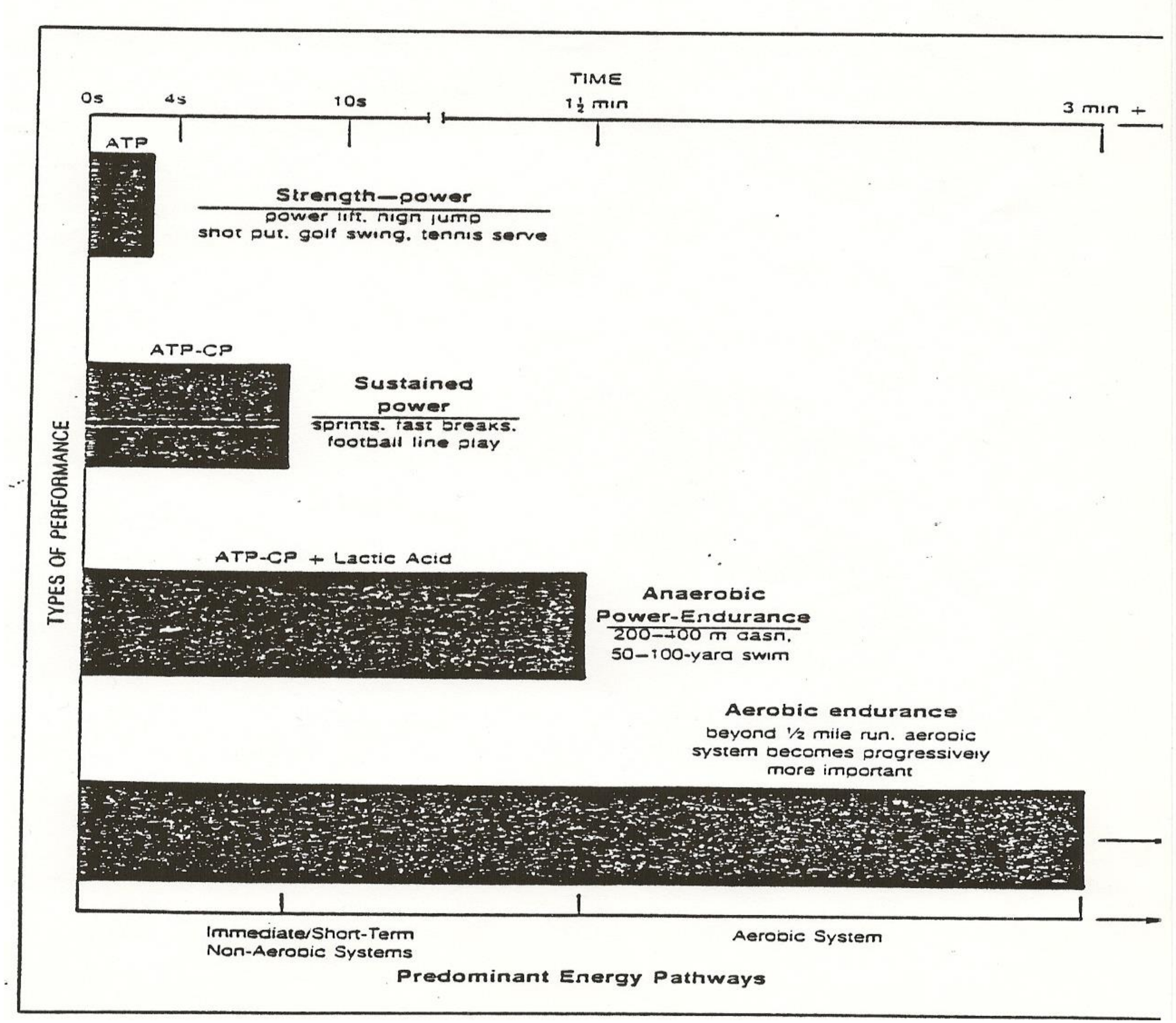
GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Primary Energy Systems With Respect To Duration and Intensity Of Activity

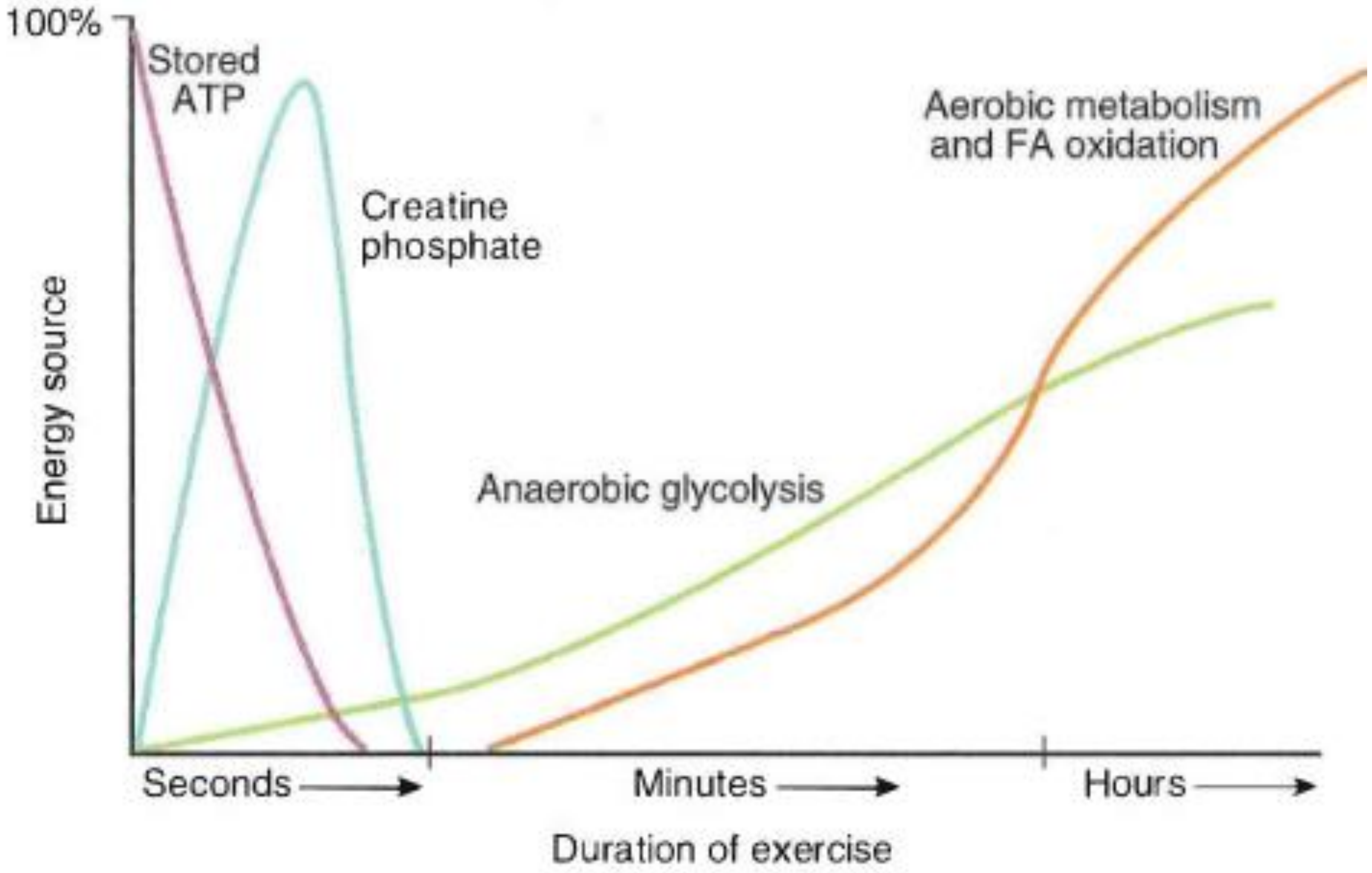
Duration of event	Intensity of event	Primary energy system(s)
0-6 s	Very intense	Phosphagen
6-30 s	Intense	Phosphagen and fast glycolysis
30 s–2 min	Heavy	Fast glycolysis
2-3 min	Moderate	Fast glycolysis and oxidative system
> 3 min	Light	Oxidative system

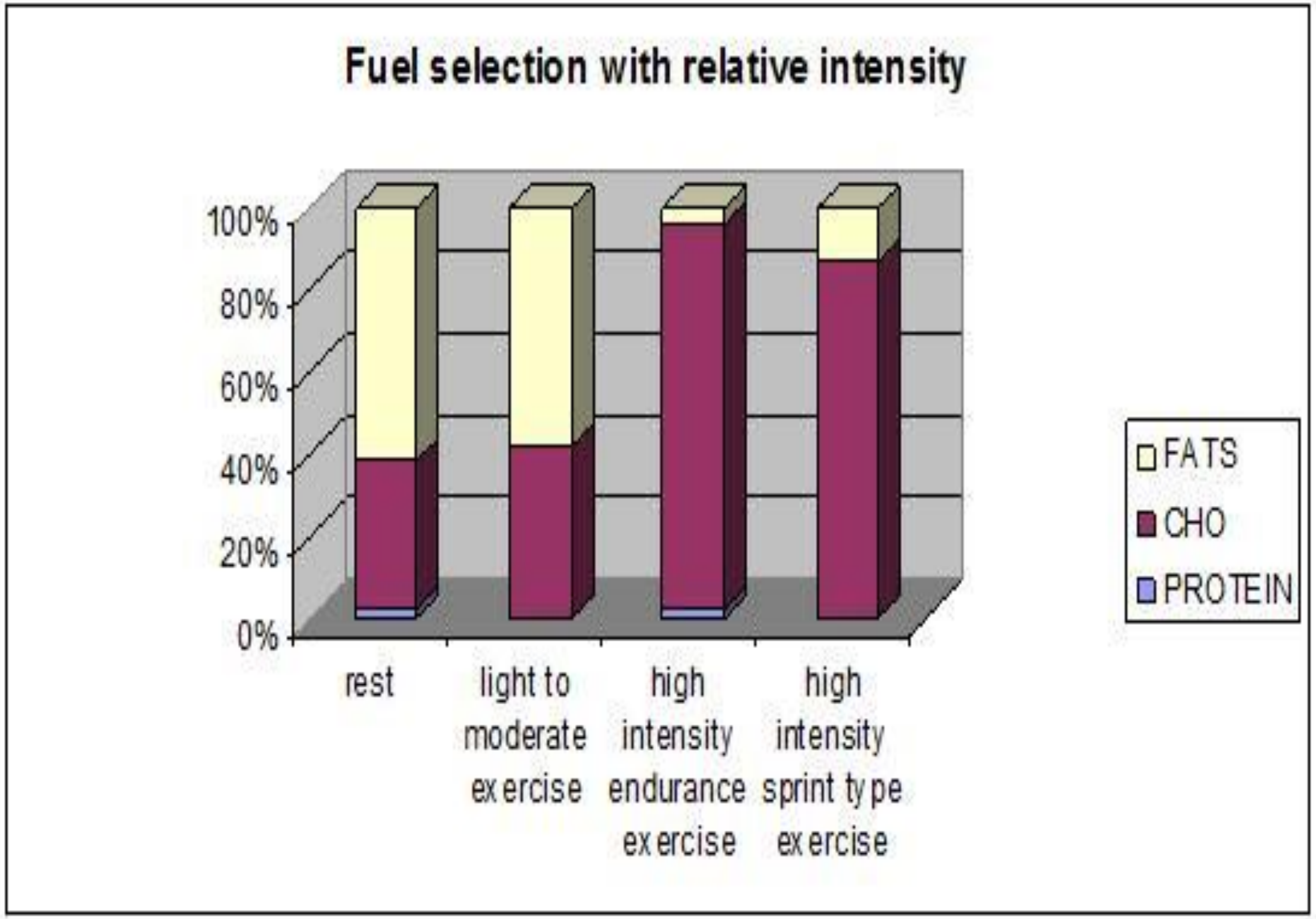
GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Primary Energy Systems Of Common Sports



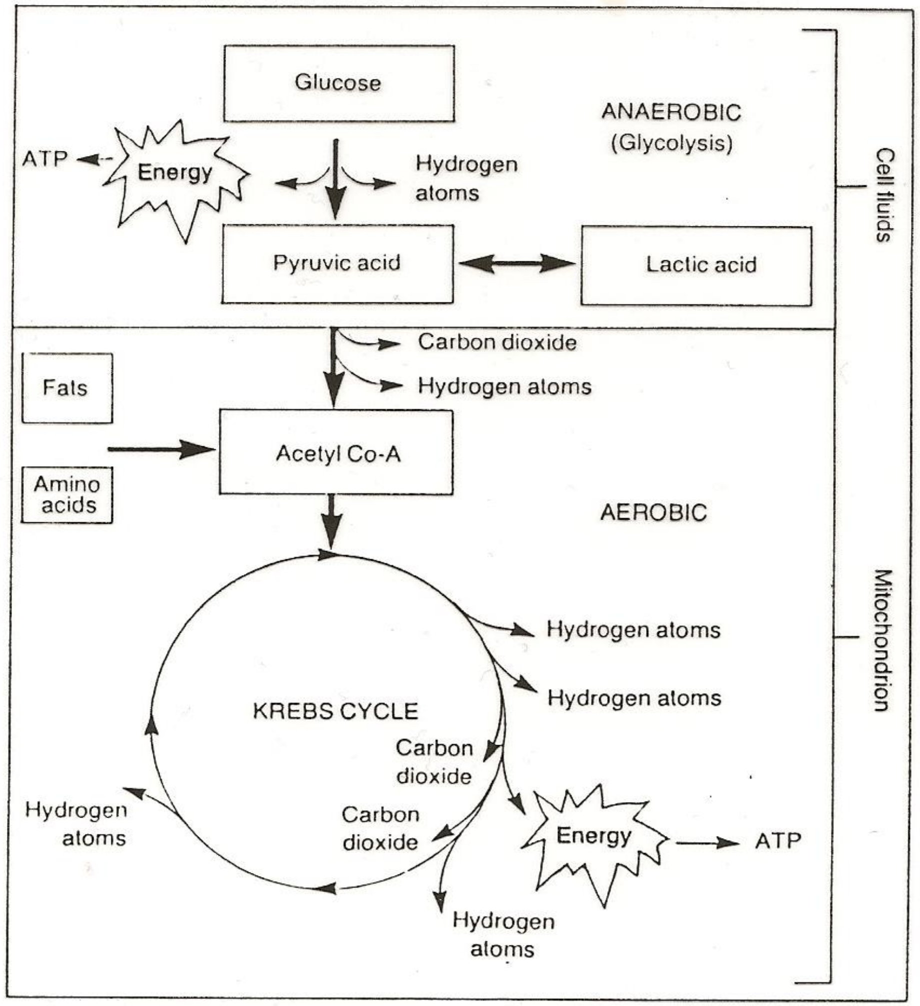
GLOBAL
INTEGRATIVE MEDICINE ACADEMY




Fuel selection with relative intensity
100%
80%
60%
40%
20%
0%
rest
light to moderate exercise
high intensity endurance exercise
high intensity sprint type exercise
FATS
CHO
PROTEIN

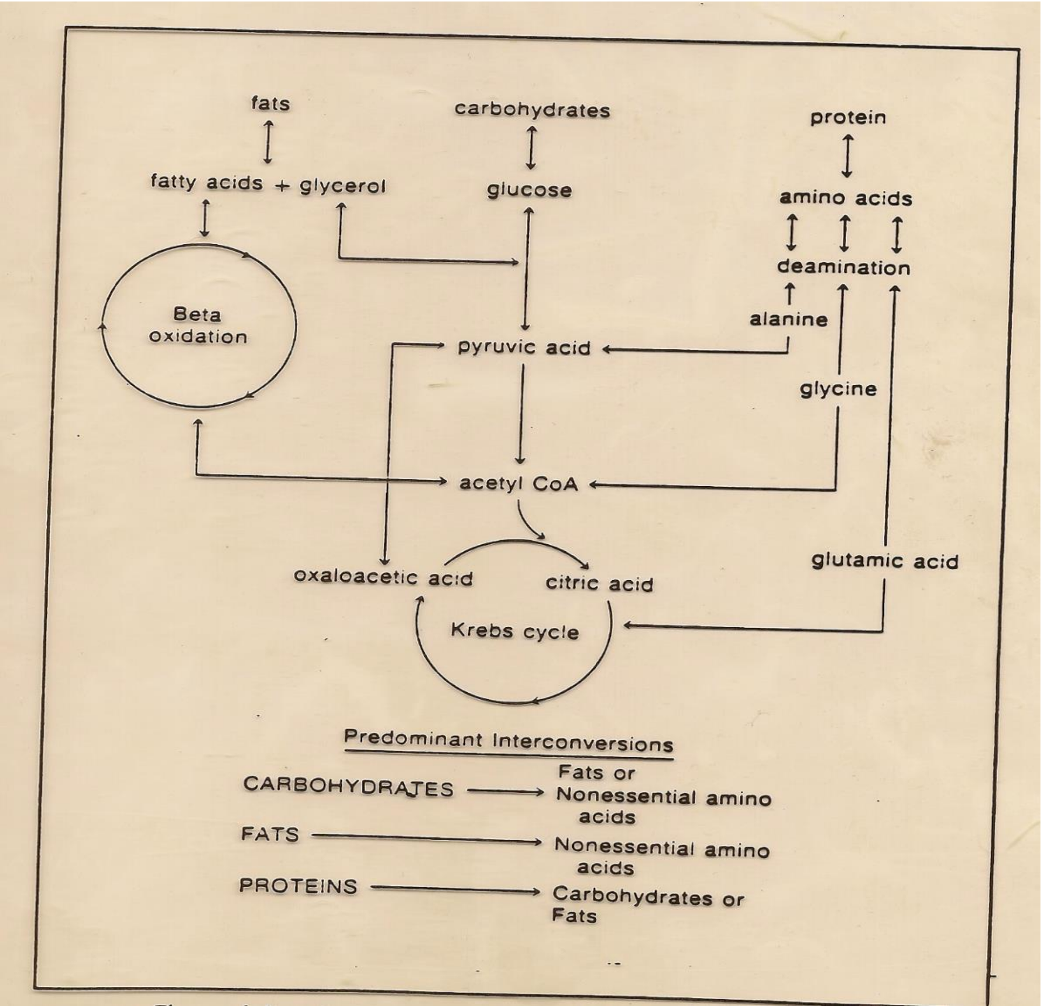
INTEGRATIVE MEDICINE ACADEMY

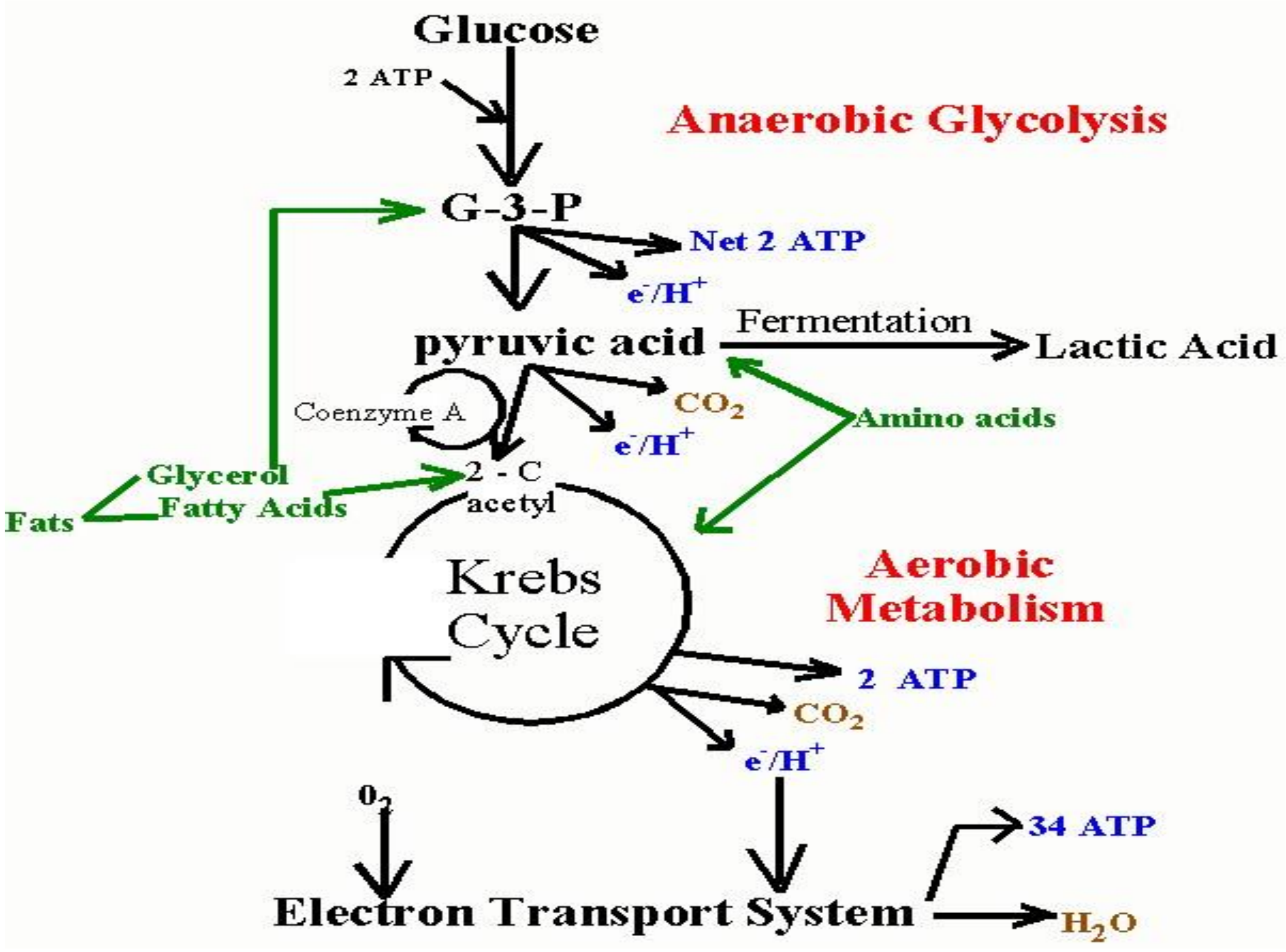
Biochemistry Of Energy Production (Overview)



GLOBAL
INTEGRATIVE MEDICINE ACADEMY

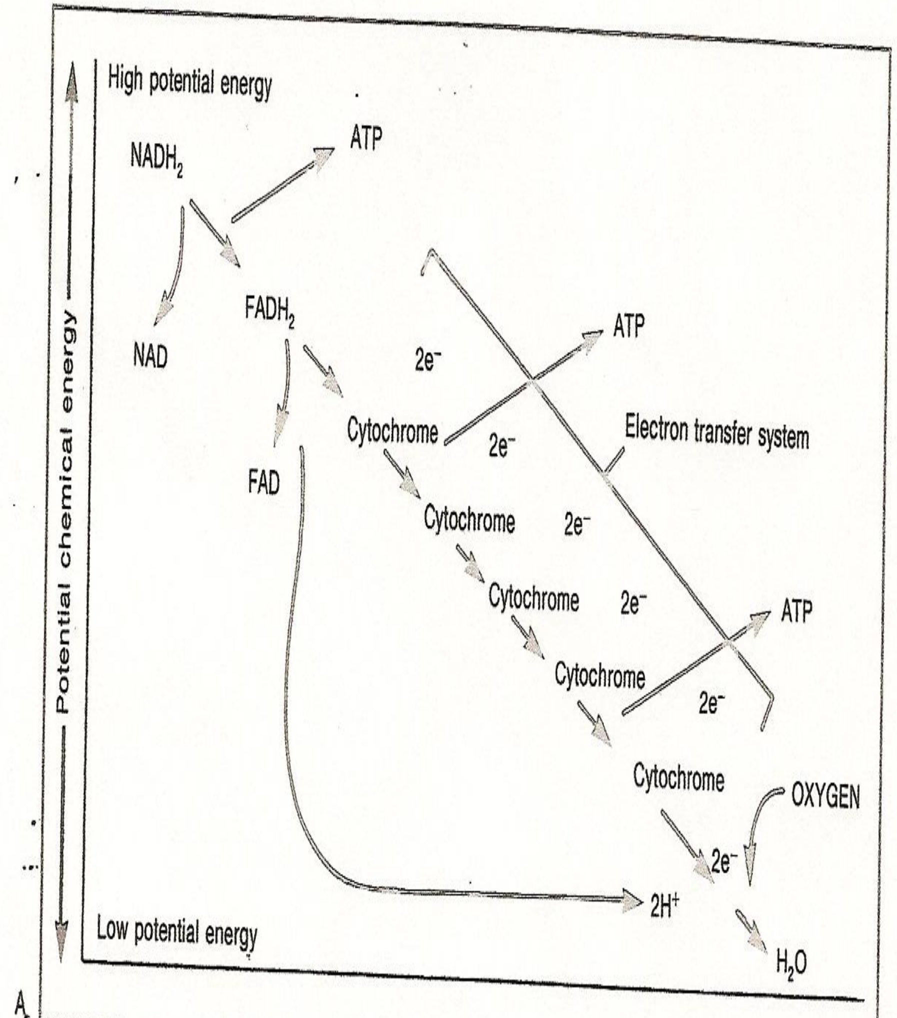
Interconversion of CHO, Protein, Fat In Energy Production

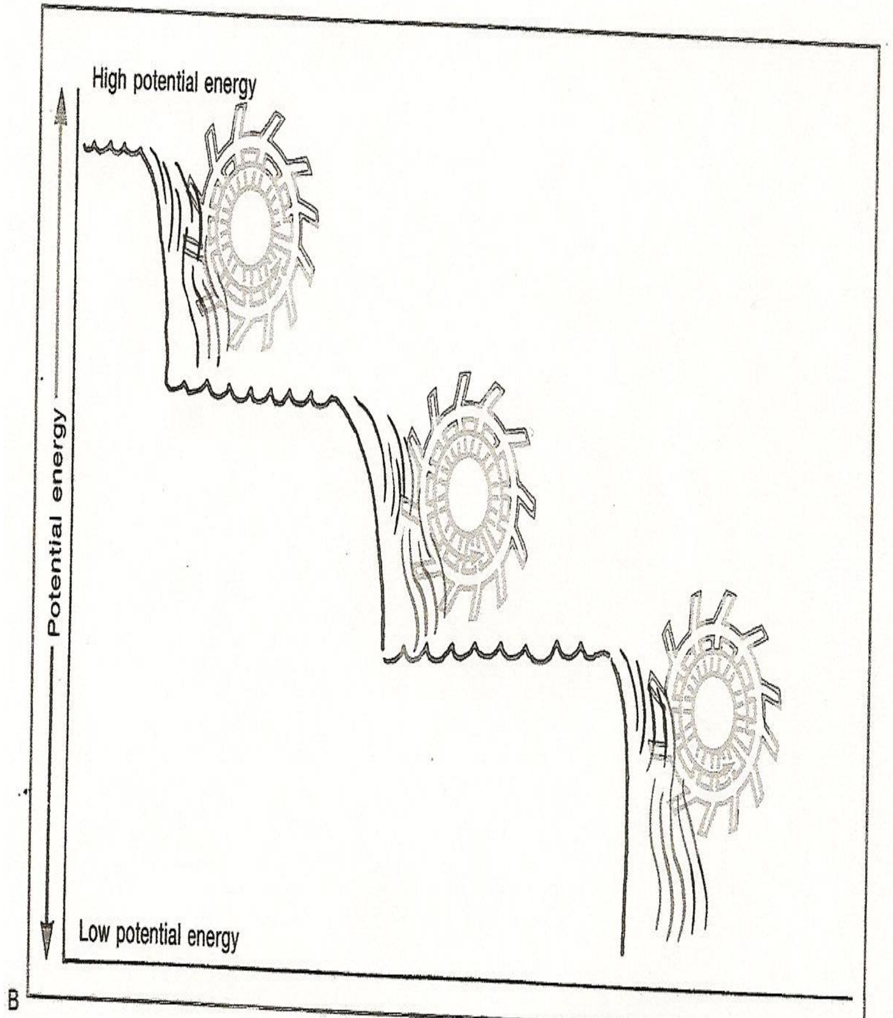



Glucose
2 ATP
Anaerobic Glycolysis
G-3-P
Net 2 ATP
e-/H+
pyruvic acid
Fermentation
Lactic Acid
Coenzyme A
CO2
e-/H+
Amino acids
Glycerol
Fatty Acids
Fats
2 - C
acetyl
Krebs
Cycle
Aerobic
Metabolism
2 ATP
CO2
e-/H+
02
34 ATP
Electron Transport System
H2O

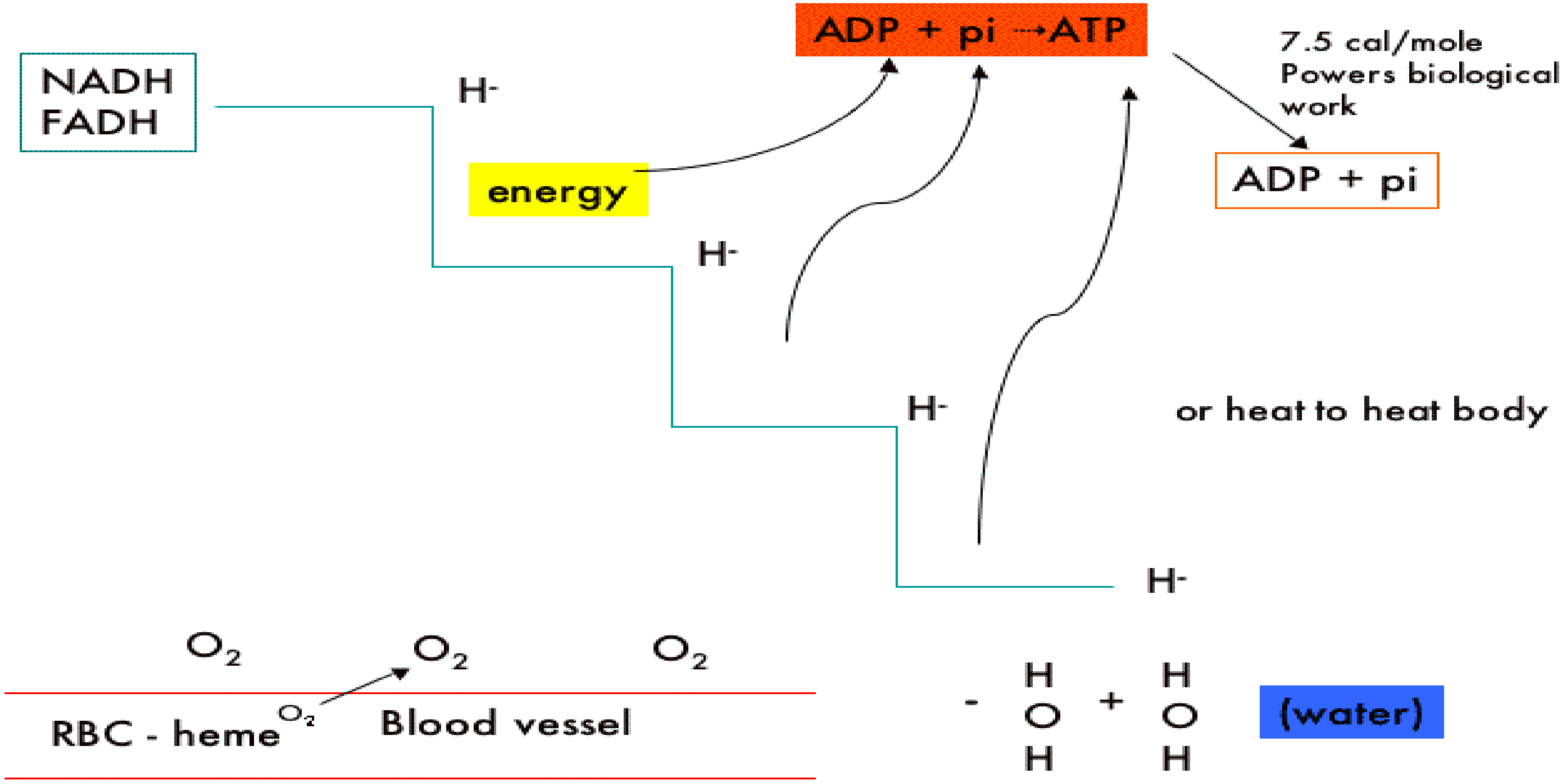
GLOBAL INTEGRATIVE MEDICINE ACADEMY

Aerobic ATP Production In The Mitochondria: Electron Transfer System





AEROBIC METABOLISM – THE SUN'S ENERGY RELEASED TO POWER BODY AS ATP



Dr. J. Meschino, DC, MS, ND ©

This is sometimes known as the hydrogen carrier system.

The carrier, NAD, is nicotinamide adenine dinucleotide. Similarly, FAD is flavine adenine dinucleotide.

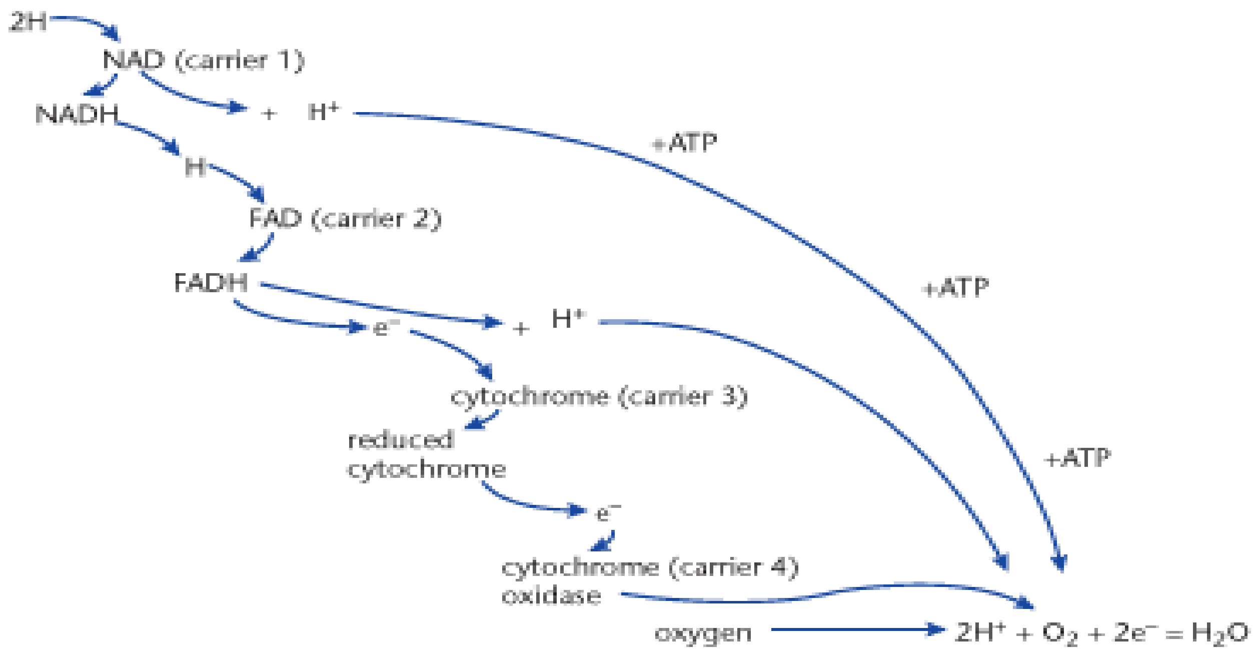
Hydrogen is not transferred to cytochrome. Instead, the 2H atoms ionise into $2H^+ + 2e^-$. H is passed via an intermediate co-enzyme Q to cytochrome.

Only the electrons are carried via the cytochromes.

e^- is an electron
H^+ is a hydrogen ion or proton.

Oxygen is needed at the end of the carrier chain as a hydrogen acceptor. This is why we need oxygen to live. Without it the generation of ATP along this route would be stopped.

An enzyme can be both an oxidoreductase and a dehydrogenase at the same time!



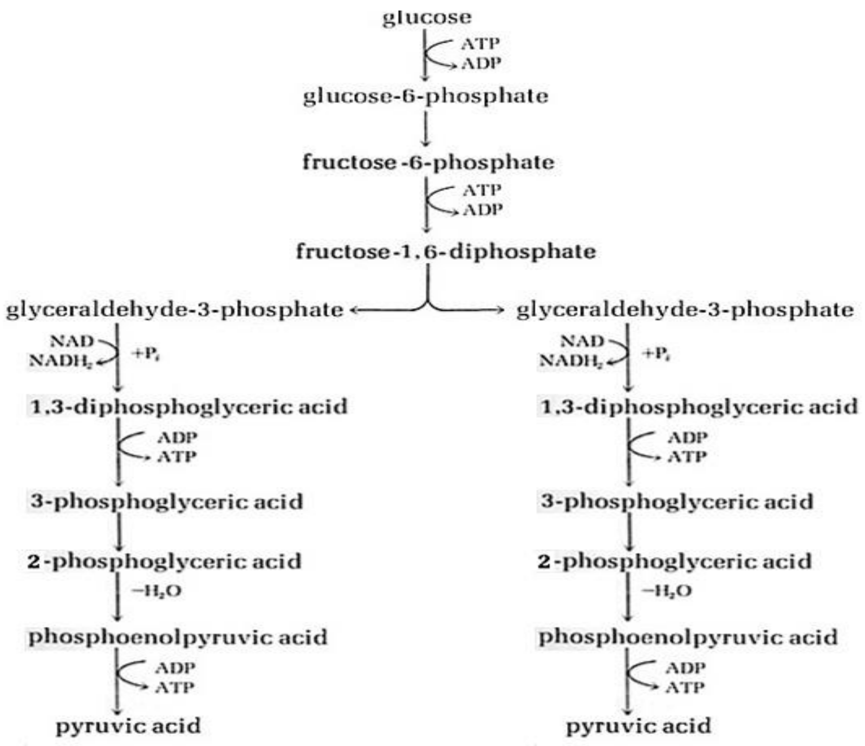
Oxidation	*Reduction*
Gain of oxygen	Loss of oxygen
Loss of hydrogen	Gain of hydrogen
Loss of electrons	Gain of electrons

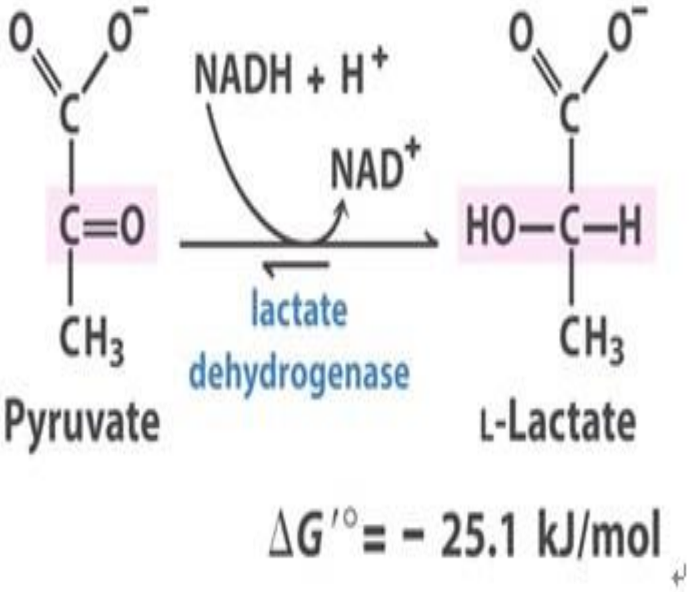
When oxidation takes place then so does reduction, simultaneously, e.g. $NADH_2$ passes H to FAD. The NAD loses hydrogen and as a result becomes oxidised. FAD gains hydrogen and becomes $FADH_2$, and is therefore reduced. The generic term for an enzyme which catalyses this is oxidoreductase. Additionally an enzyme which removes hydrogen from a molecule is a dehydrogenase.

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

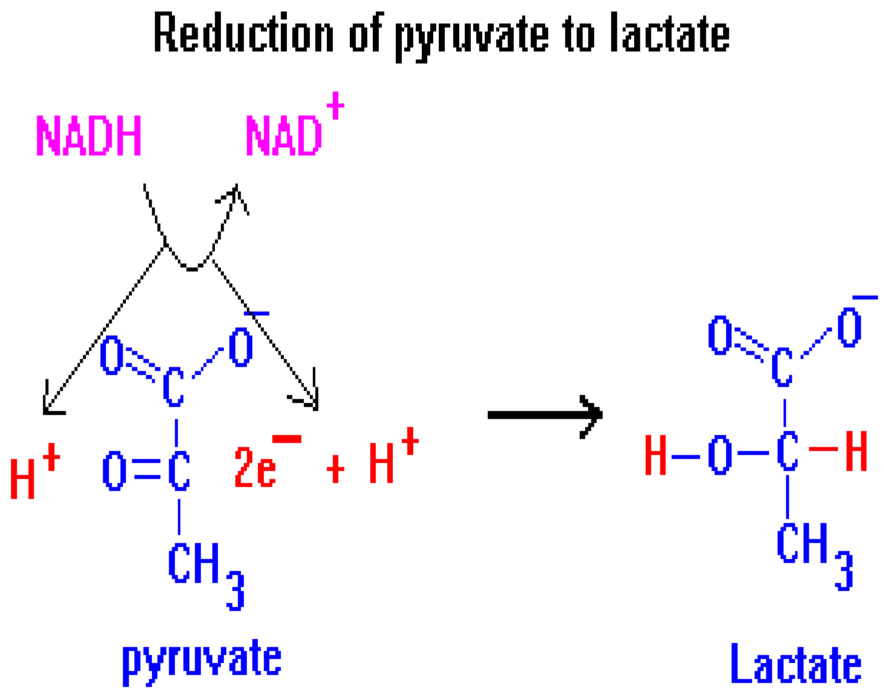
Lactic Acid: When Oxygen Demand Exceeds Supply –

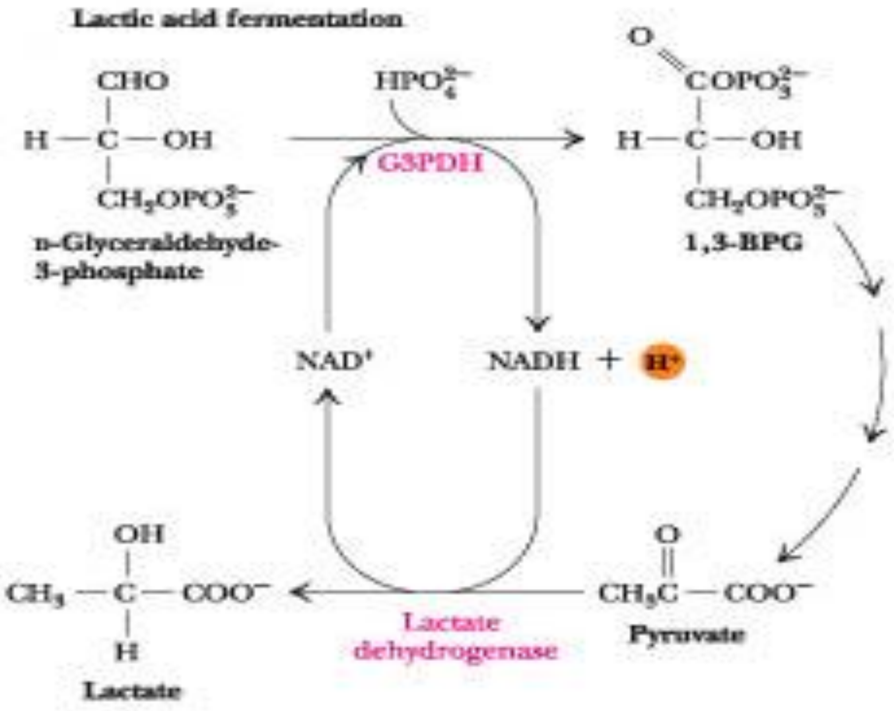
In Anaerobic Exercise, Hypoxia from atherosclerosis, Congestive Heart Failure – NADH formed in conversion of glyceraldeyde-3 phosphate to 1,3 diphosphoglyceric acid cannot pass Hydrogen to oxidative phosphorylation due to insufficient oxygen, so Hydrogens attached to pyruvate to form lactic acid





Lactic Acid Formation in Fast Glycolysis or Above Aerobic Threshold whereby Insufficient O2 in Cell for All Hydrogen Electrons on NADH to be Passed along Mitochondrial Chain – therefor NADH formed from Glyceraldehyde 3 Phosphate attached to Pyruvate to Form Lactic Acid (Lactate). During Submax recovery or rest, once oxygen debt is being repaid, NAD can pick up hydrogens from lactic acid (as NADH) and deliver them to Electron Transfer System to generate ATP aerobically (with water and CO2 formation as end-products). Or lactic acid enter the Cori Cycle.





GLOBAL INTEGRATIVE MEDICINE ACADEMY

Cori Cycle: Recycling Of Lactic Acid To Glucose During Rest And Submax Period Of Interval Training

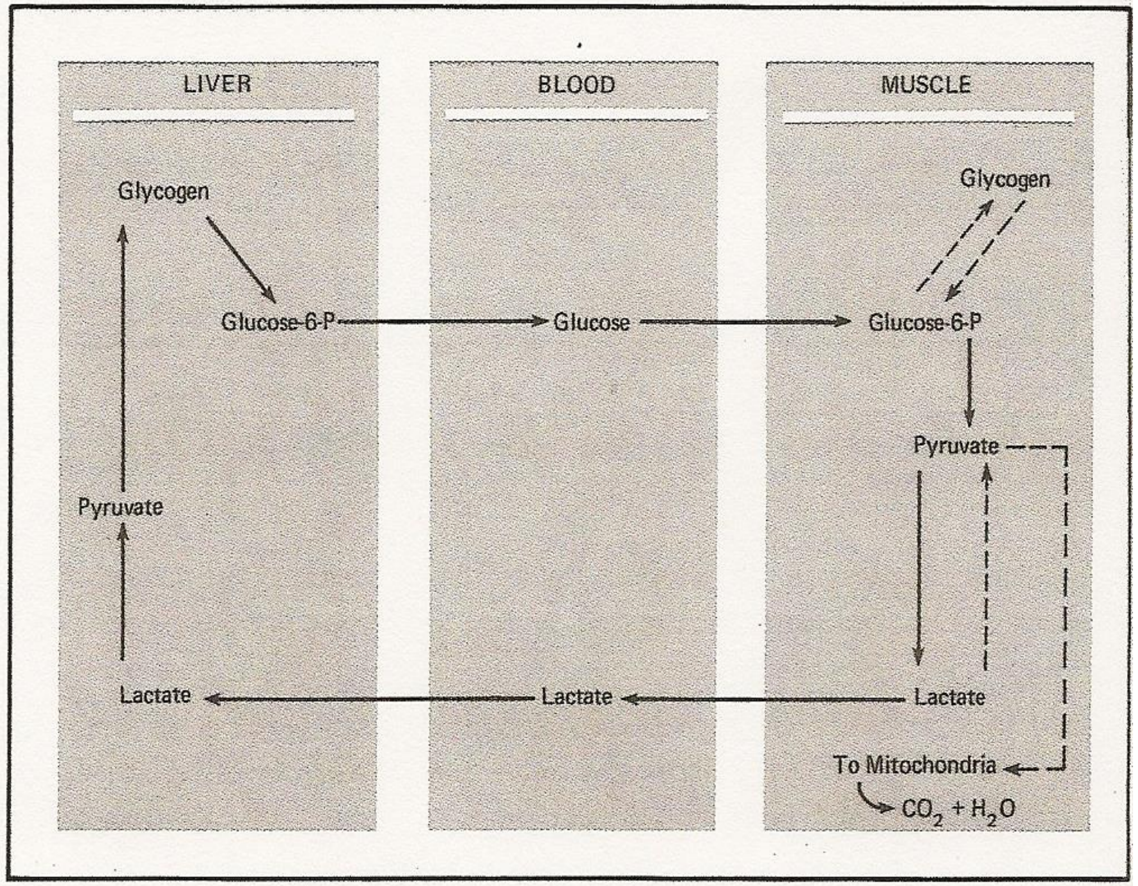
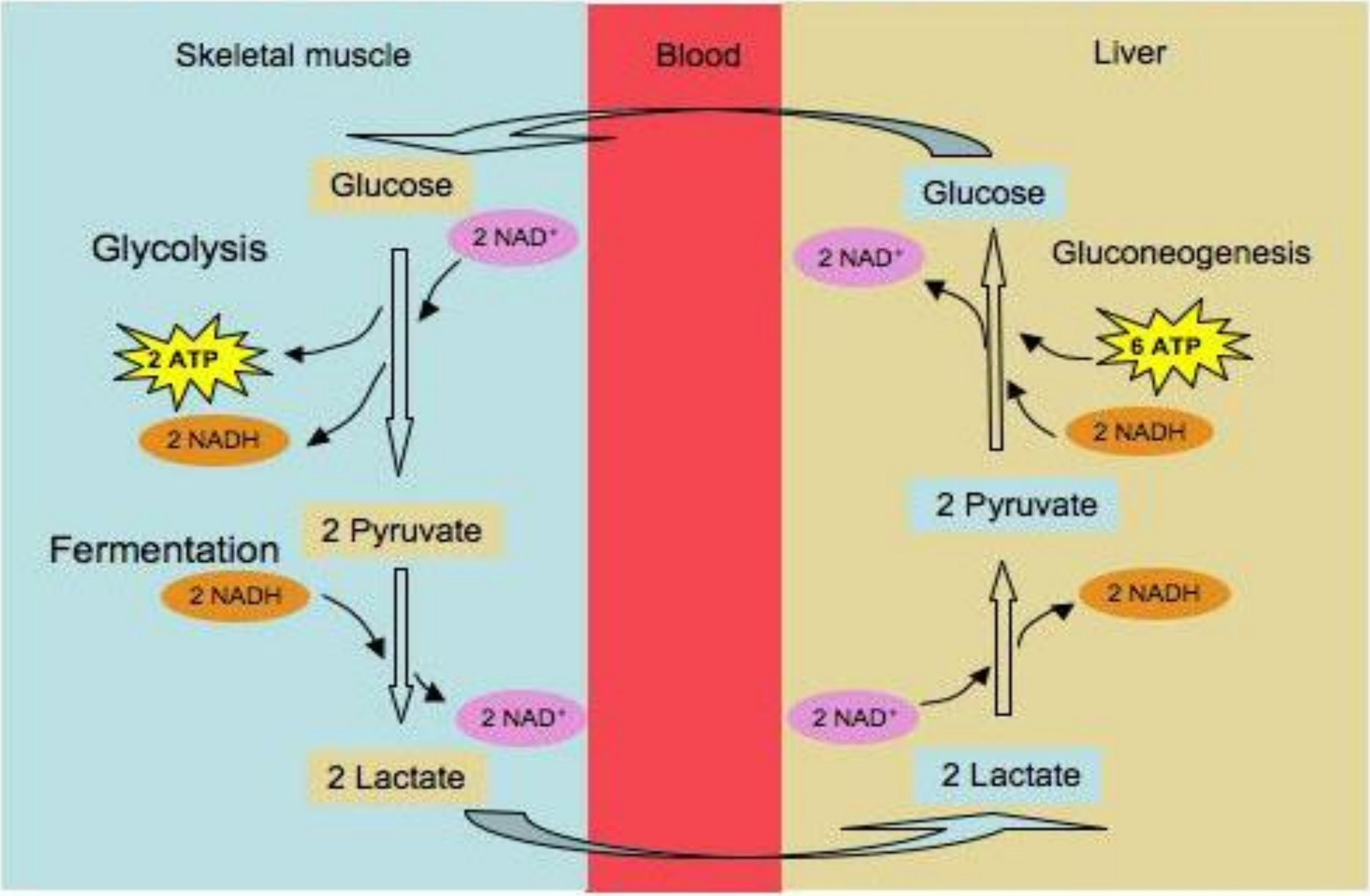


FIGURE 4.3. Major pathways for lactic acid (lactate) removal. The Cori cycle is diagrammed with solid lines.

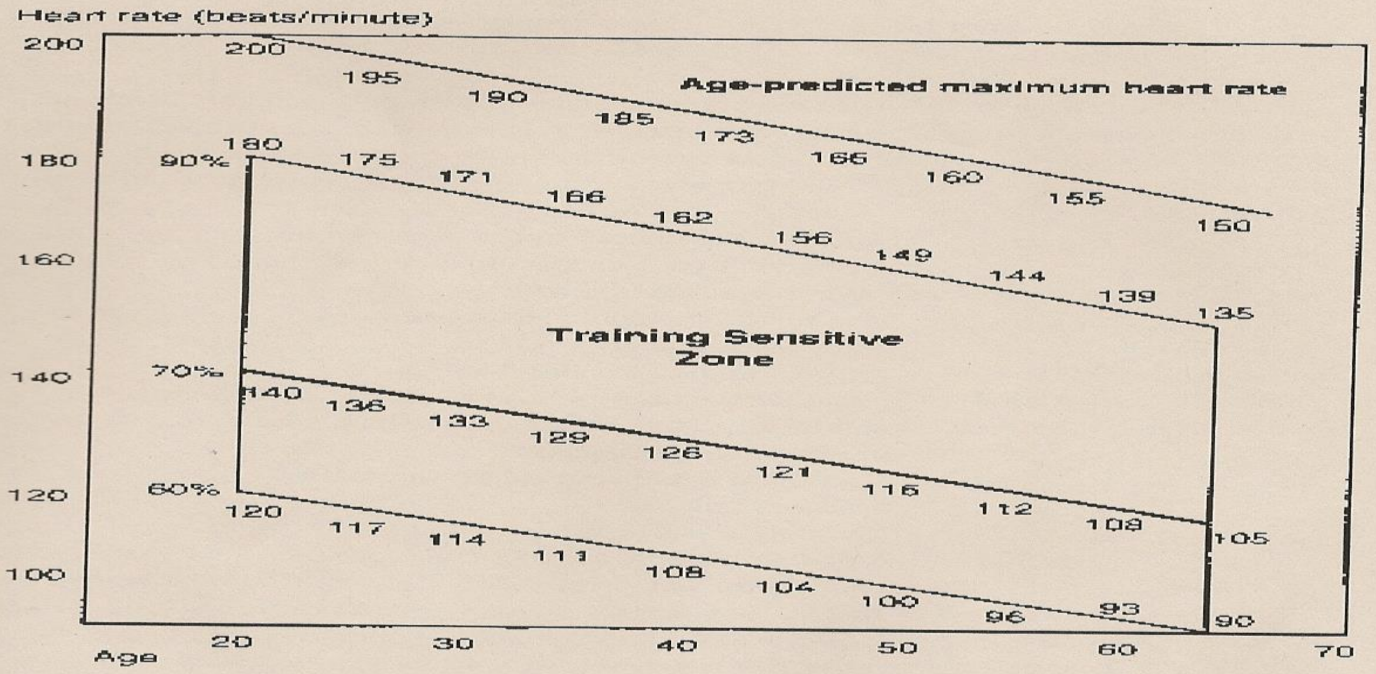
GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Cori Cycle Links Glycolysis in Muscle Cells and Gluconeogenesis in Liver



GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Aerobic Training Zone: 220 – Age = Max Attainable Heart Rate. Aerobic Zone is roughly 60-90% of Max Attainable Heart Rate

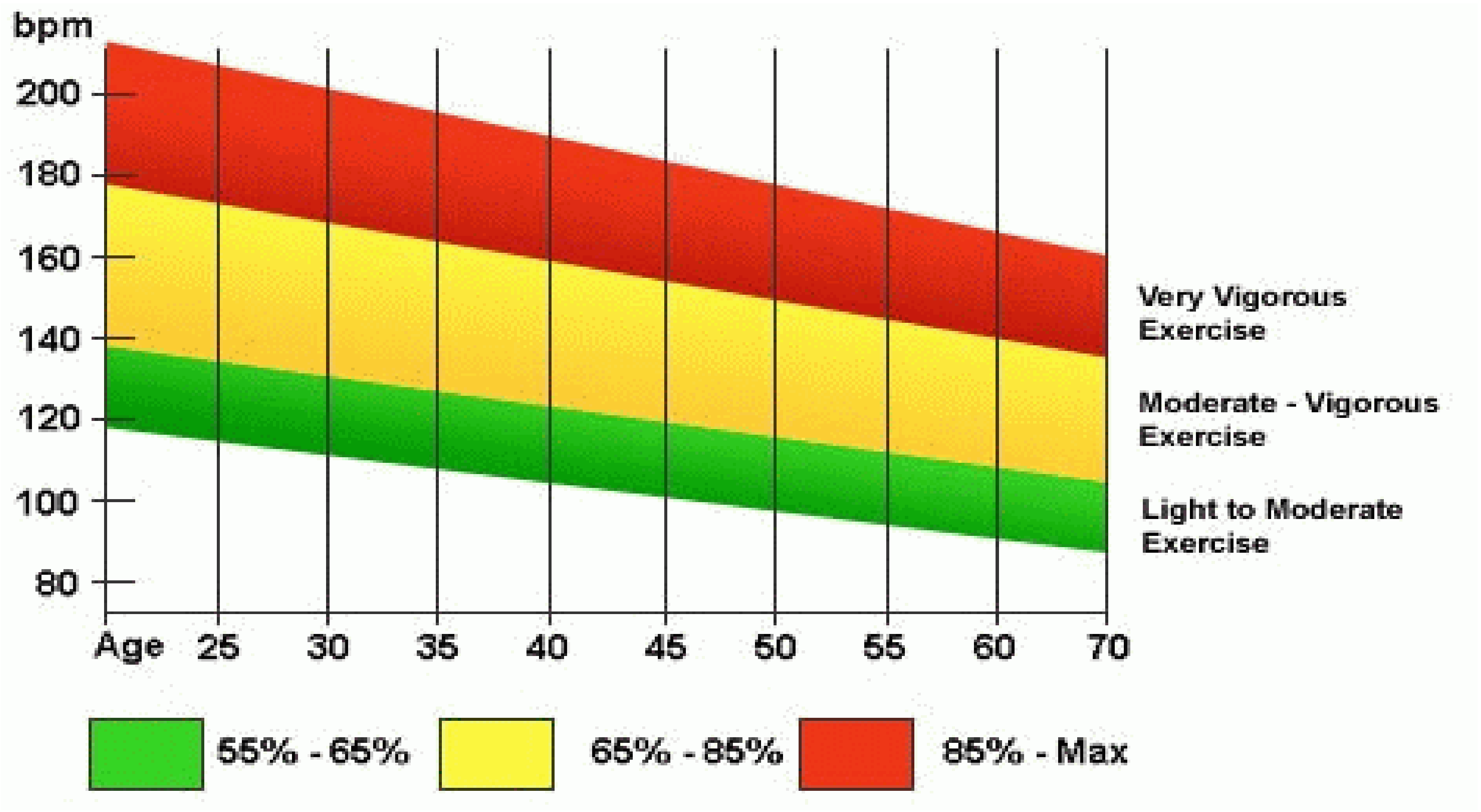


Maximal heart rates and training sensitive zones for use in aerobic training programs for people of different ages. The zone between 60 – 70% of your maximum heart rate is sufficient to derive aerobic benefits and at the same time is not so demanding as to produce significant discomfort.

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Typical Target Heart Rate Chart in Fitness Clubs

GLOBAL
INTEGRATIVE MEDICINE ACADEMY



GLOBAL
INTEGRATIVE MEDICINE ACADEMY

VO2 Max Rating Scale

Female (values in ml/kg/min)

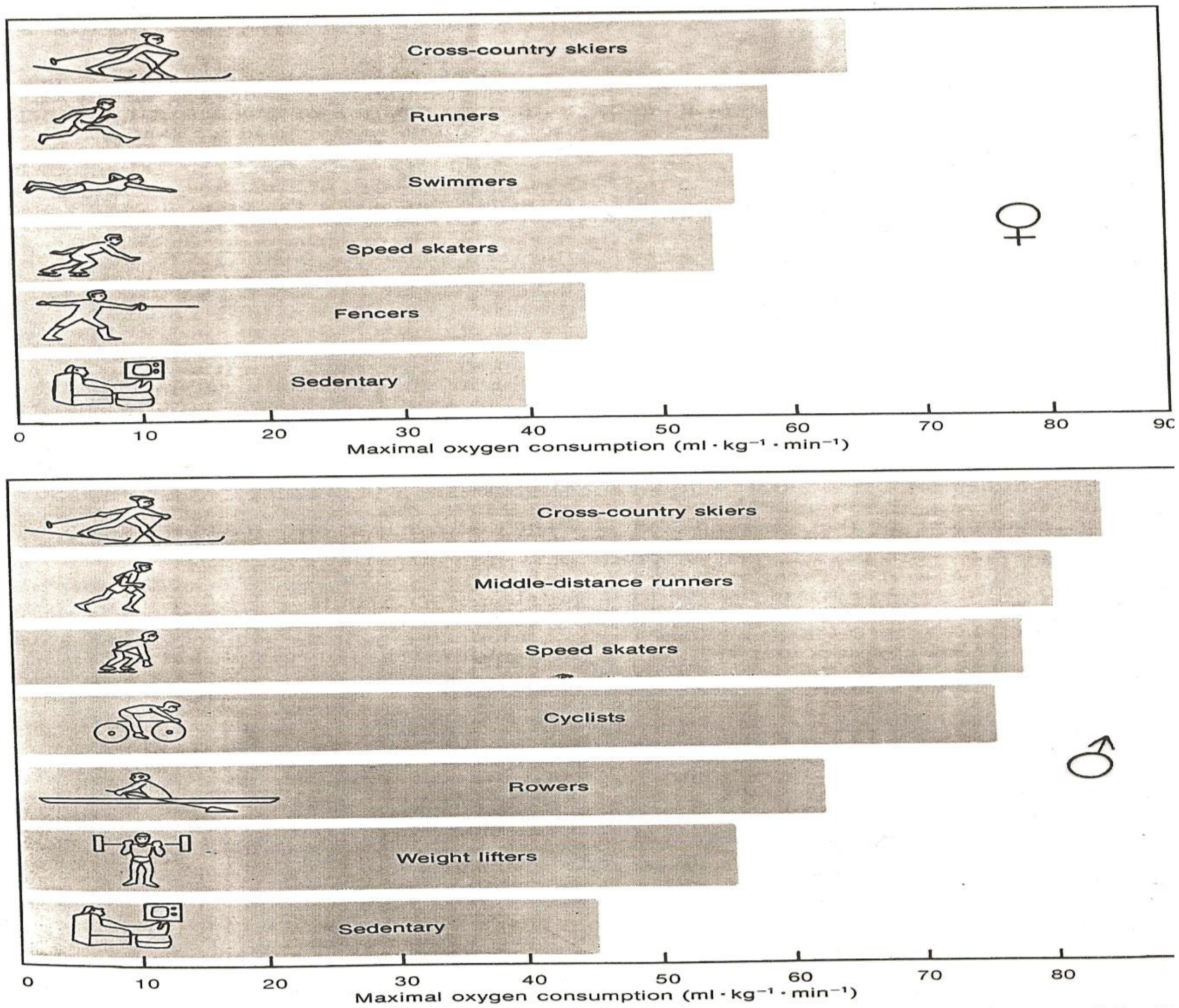
Age	Very Poor	Poor	Fair	Good	Excellent	Superior
13-19	< 25.0	25.0 – 30.9	31.0 – 34.9	35.0 – 38.9	39.0 – 41.9	> 41.9
20-29	< 23.6	23.6 – 28.9	29.0 – 32.9	33.0 – 36.9	37.0 – 41.0	> 41.0
30-39	< 22.8	22.8 – 26.9	27.0 – 31.4	31.5 – 35.6	35.7 – 40.0	> 40.0
40-49	< 21.0	21.0 – 24.4	24.5 – 28.9	29.0 – 32.8	32.9 – 36.9	> 36.9
50-59	< 20.2	20.2 – 22.7	22.8 – 26.9	27.0 – 31.4	31.5 – 35.7	> 35.7
60 +	< 17.5	17.5 – 20.1	20.2 – 24.4	24.5 – 30.2	30.3 – 31.4	> 31.4

Male (values in ml/kg/min)

Age	Very Poor	Poor	Fair	Good	Excellent	Superior
13-19	< 35.0	35.0 – 38.3	38.4 – 45.1	45.2 – 50.9	51.0 – 55.9	> 55.9
20-29	< 33.0	33.0 – 36.4	36.5 – 42.4	42.5 – 46.4	46.5 – 52.4	> 52.4
30-39	< 31.5	31.5 – 35.4	35.5 – 40.9	41.0 – 44.9	45.0 – 49.4	> 49.4
40-49	< 30.2	30.2 – 33.5	33.6 – 38.9	39.0 – 43.7	43.8 – 48.0	> 48.0
50-59	< 26.1	26.1 – 30.9	31.0 – 35.7	35.8 – 40.9	41.0 – 45.3	> 45.3
60+	< 20.5	20.5 – 26.0	26.1 – 32.2	32.3 – 36.4	36.5 – 44.2	> 44.2

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

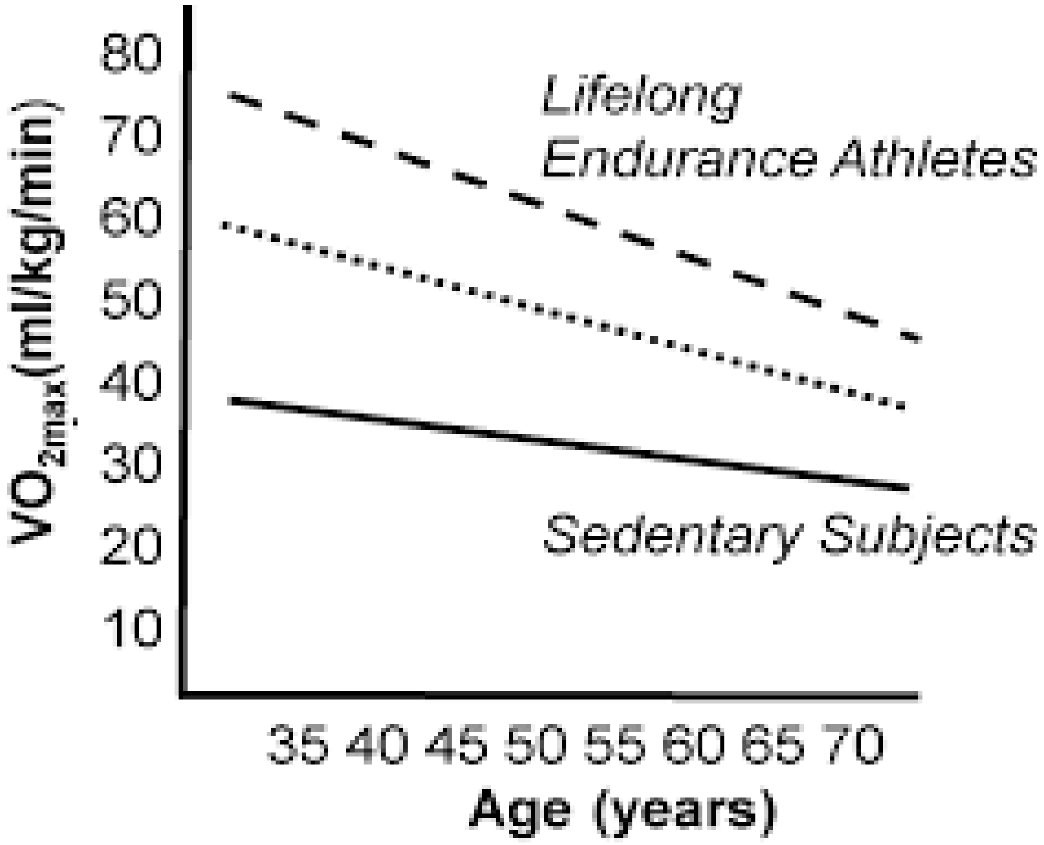
Max Oxygen Utilization (VO_2 Max) – ml/kg/min



GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Elite Athletes (left) and Decline In VO2 Max with Age, but still better than Sedentary Subjects

Athlete	Event	VO2 Max
Bjorn Daehlie	Cross country skier	90.0
Miguel Indurain	Cyclist (winner of Tour de France)	88.0
John Ngugi	5 times world cross country champ	85.0
Dave Bedford	10km World Record holder	85.0
Steve Prefontaine	1 mile in 3:54.6	84.4
Lance Armstrong	Cyclist (winner of Tour de France)	84.0
Joan Benoit	Marathon runner (2:24:52)	78.6
Bill Rodgers	Marathon runner (2:09:27)	78.5
Sebastian Coe	Middle distance (1 mile WR)	77.0
Grete Waitz	Marathon runner (WR 1980)	73.0
Frank Shorter	Marathon runner	71.0
Derek Clayton	Marathon runner (WR 1969)	69.7



Adaptations To Aerobic Exercise

- Increased no.& size of mitochondria in slow twitch m. fibers
- Increased oxidative enzymes in slow twitch m. fibers
- Increased VO2 Max (oxygen uptake or consumption)
- Increased fat-burning capacity in muscles
- Increased myoglobin in slow twitch m. fibers
- Increased glycogen storage
- Increased intramuscular fat in slow twitch m.fibers

Central Adaptations:

- Athletes pulse – increased blood flow to myocardium
- Increased collateral circulation in heart muscle
- Decreased catecholamine sensitivity
- Increased stroke volume
- Increased insulin sensitivity (glucose tolerance, lipogenesis, sodium resorption, glycosylated hemoglobin and AGE-Proteins)
- Decreased Blood Pressure in many cases

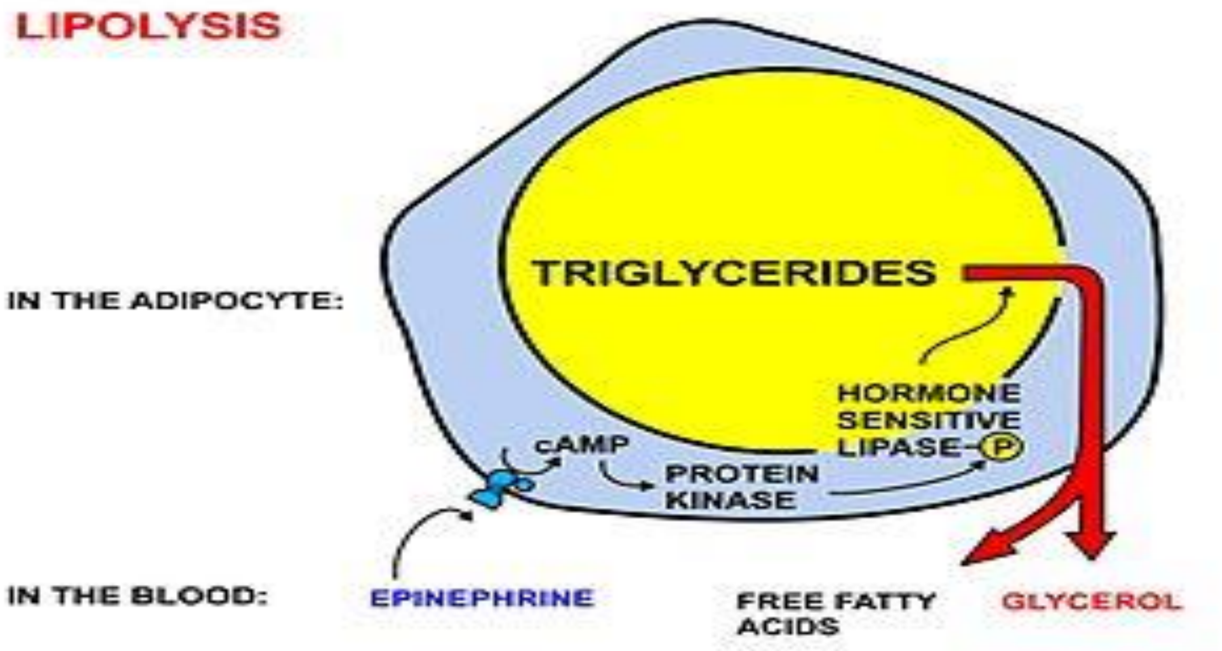
Epinephrine released by SNS once cross into aerobic zone, stimulates beta- adrenergic receptors on adipocytes, which in turn release FFA and glycerol to blood stream from lipolysis

Adrenergic Receptors

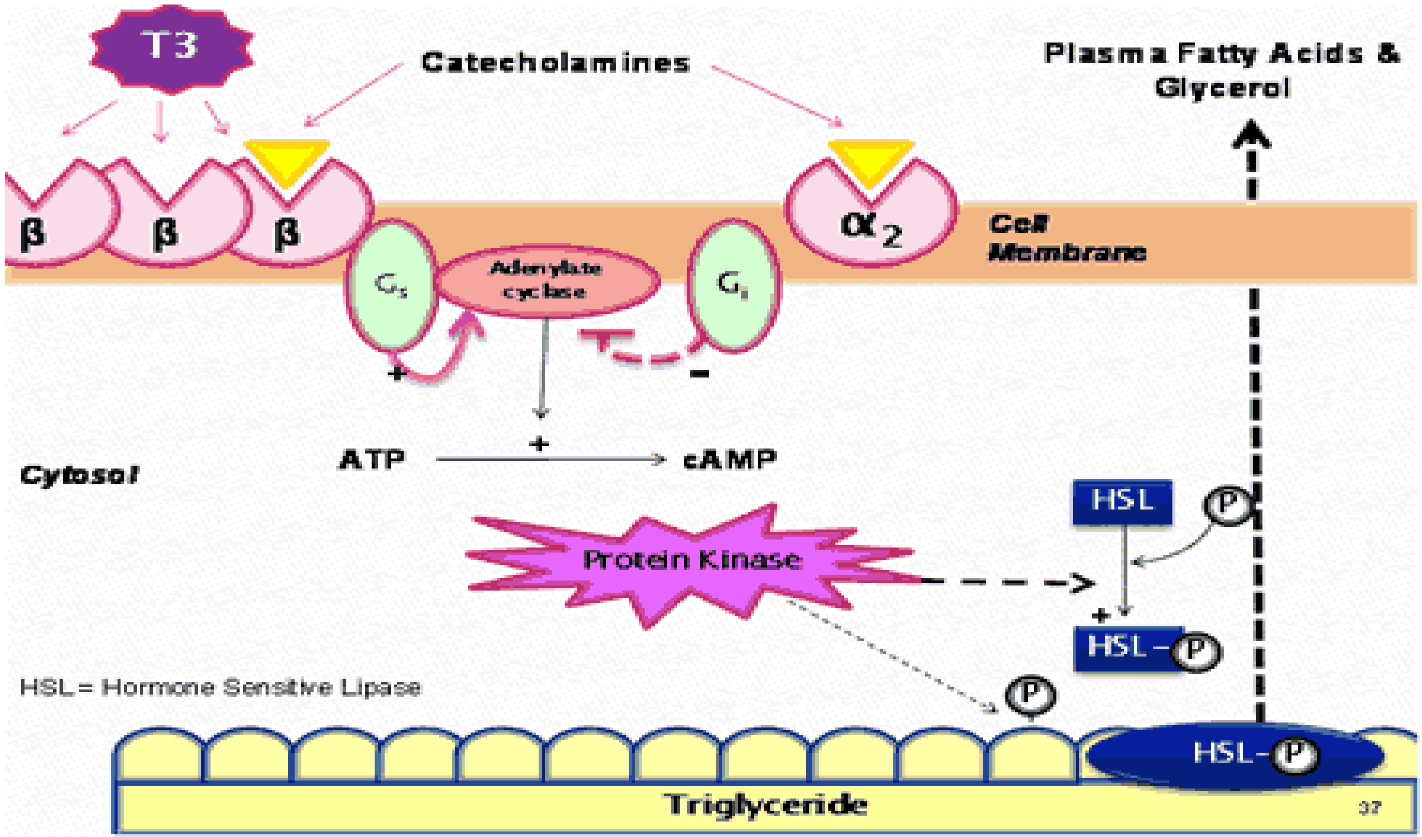
- Alpha Receptors:
  - α_1: Contraction of vascular and genitourinary smooth muscle.
  - α_2: Contraction of vascular smooth muscle; decreased insulin secretion; aggregation of platelets; pre-synaptic inhibition of NE.
- Beta Receptors:
  - β_1: Positive inotropic and chronotropic effects on the heart.
  - β_2: Relaxes vascular, bronchial, gastrointestinal and genitourinary smooth muscle; stimulates glyconenolysis and gluconeogenesis in the liver.
  - β_3: Lipolysis in adipose tissue.

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Lipolysis in Fat Cell from epinephrine stimulation and activation of hormone-sensitive lipase-lipolysis



Note role of cAMP in lipoprotein lipase activation: Coleus Forskolin has shown promise to increase lipolysis in stubborn weight loss as it increase cAMP levels.



GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Substrate Oxidation Of Blood-borne CHO and FFA Relative To Exercise Duration – open box is oxidation of non-blood borne fuels (muscle glycogen, fat, protein)

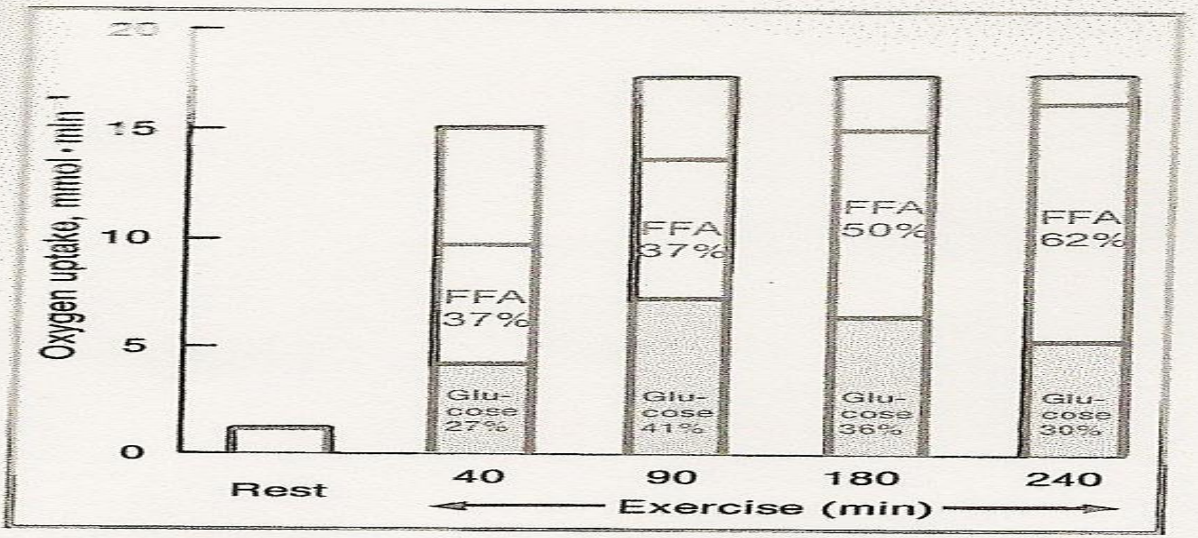
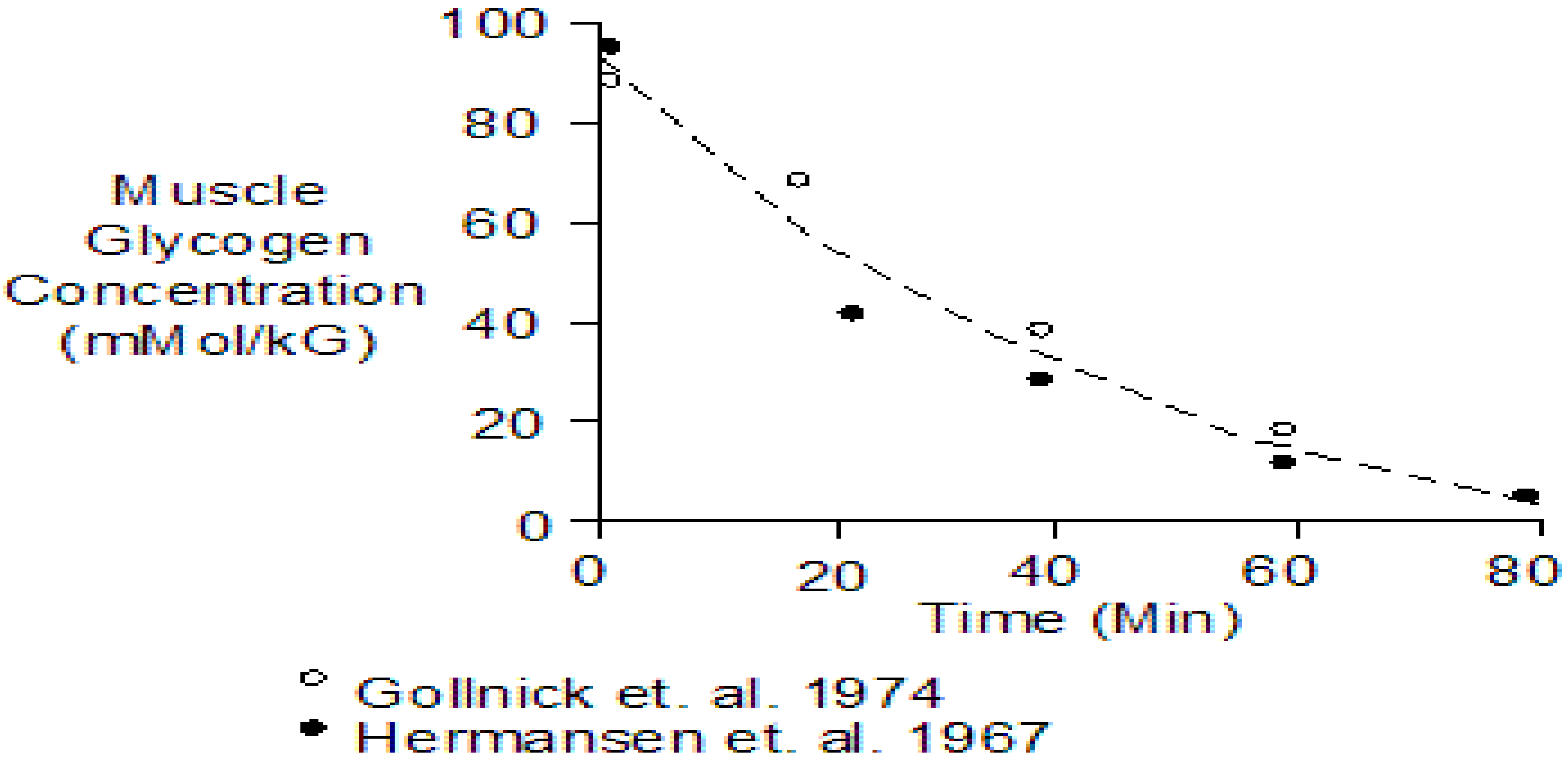
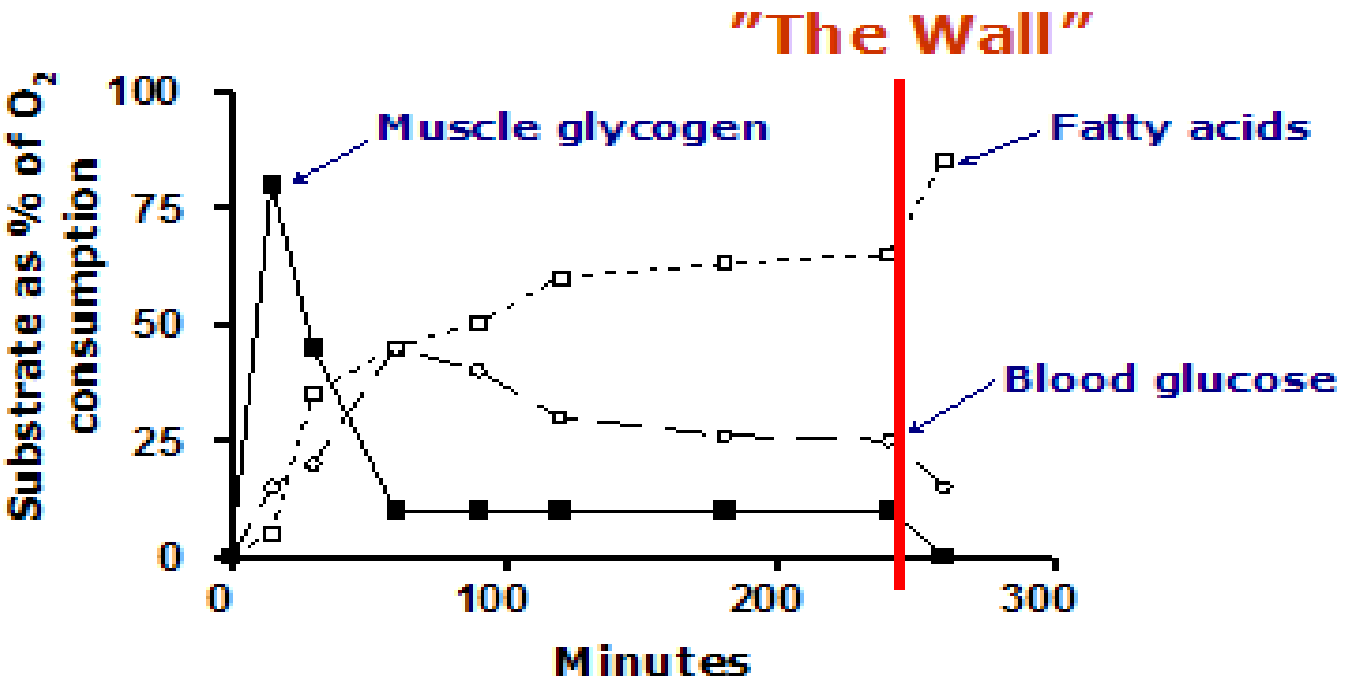


FIG. 1-8. *Uptake of oxygen and nutrients by the legs during prolonged exercise. Shaded areas represent the proportion of total oxygen uptake contributed by the oxidation of free fatty acids (FFA) and blood glucose. Open portions indicate the oxidation of non-blood-borne fuels (muscle glycogen and intramuscular fats and proteins). (From Ahlborg, G., et al.: Substrate turnover during prolonged exercise in man. J. Clin. Invest, 53: 1080, 1974.)*

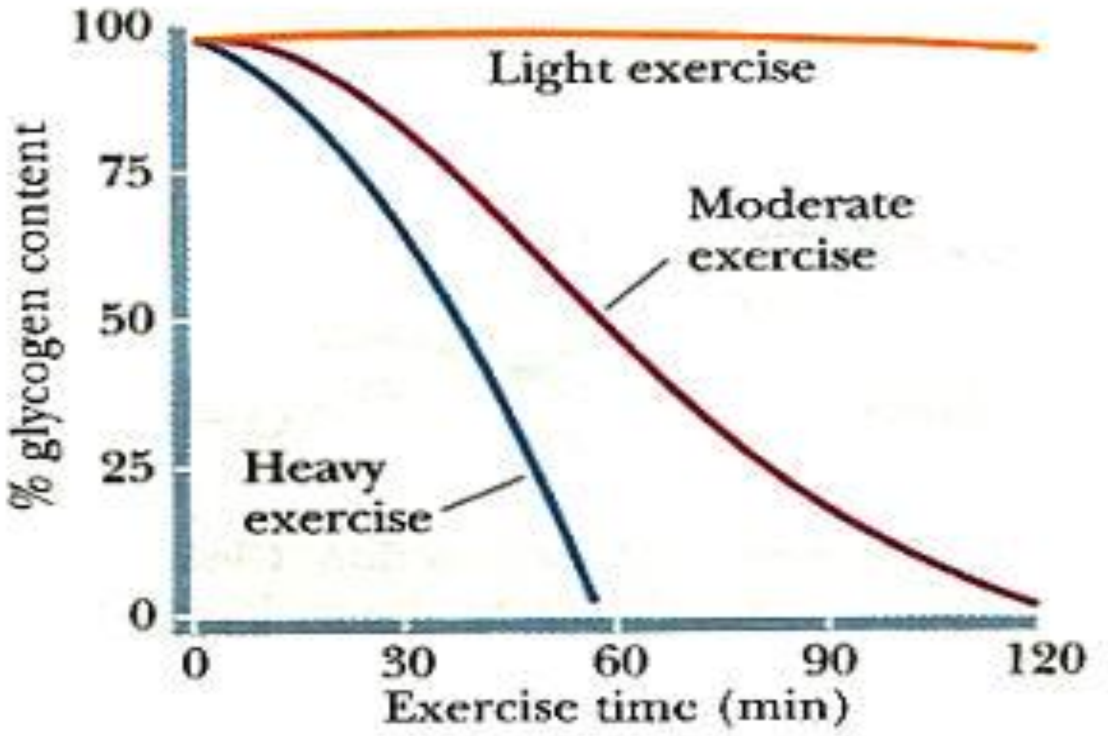

100
80
60
40
20
0
Muscle Glycogen Concentration (mMol/kG)
0
20
40
60
80
Time (Min)
Gollnick et. al. 1974
Hermansen et. al. 1967

Energy Sources in Working Muscle

Time Interval and Choice of Substrate



Glycogen Utilization in Working Muscle



Biochemistry, 3. ed, Garrett and Grisham, 2004, p. 772

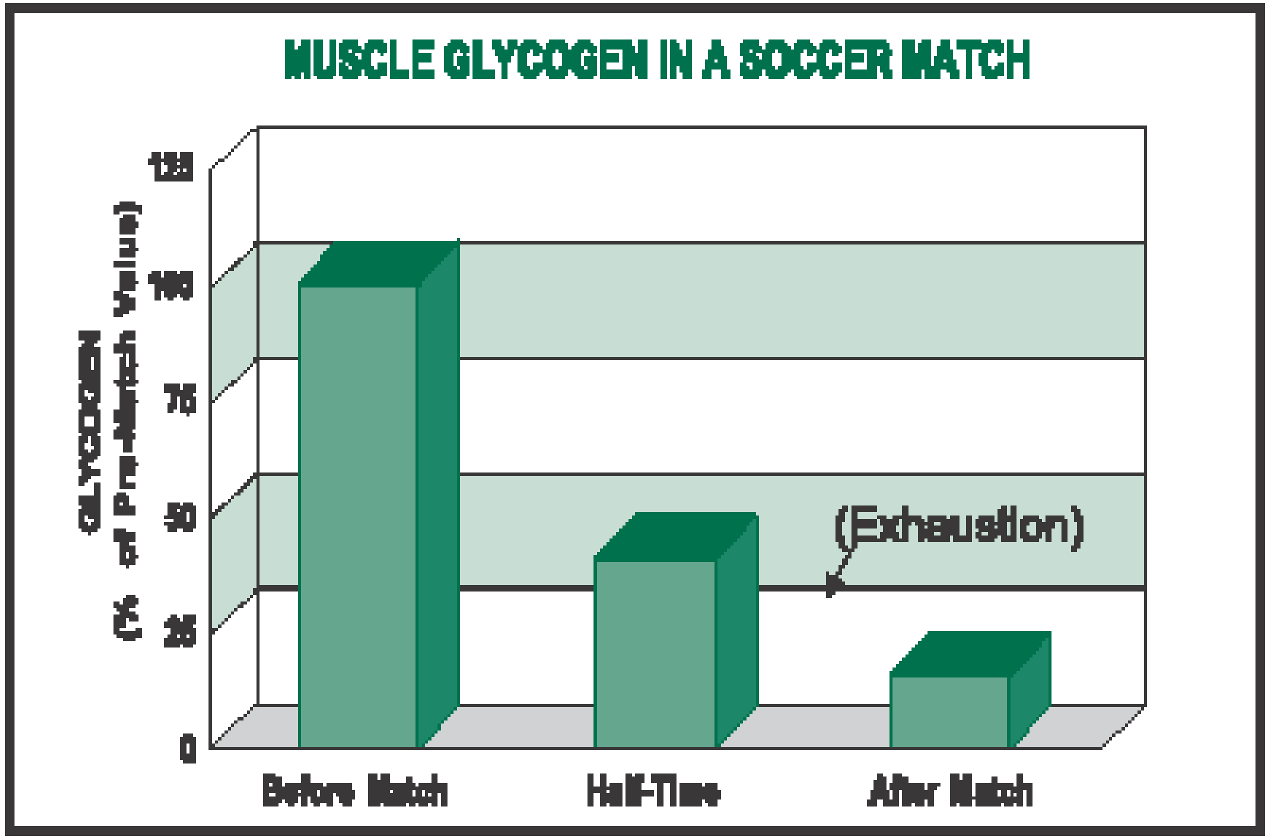


FIGURE 1. Effect of match play in soccer on stores of glycogen in leg muscles. Modified from Agnevik (1970).

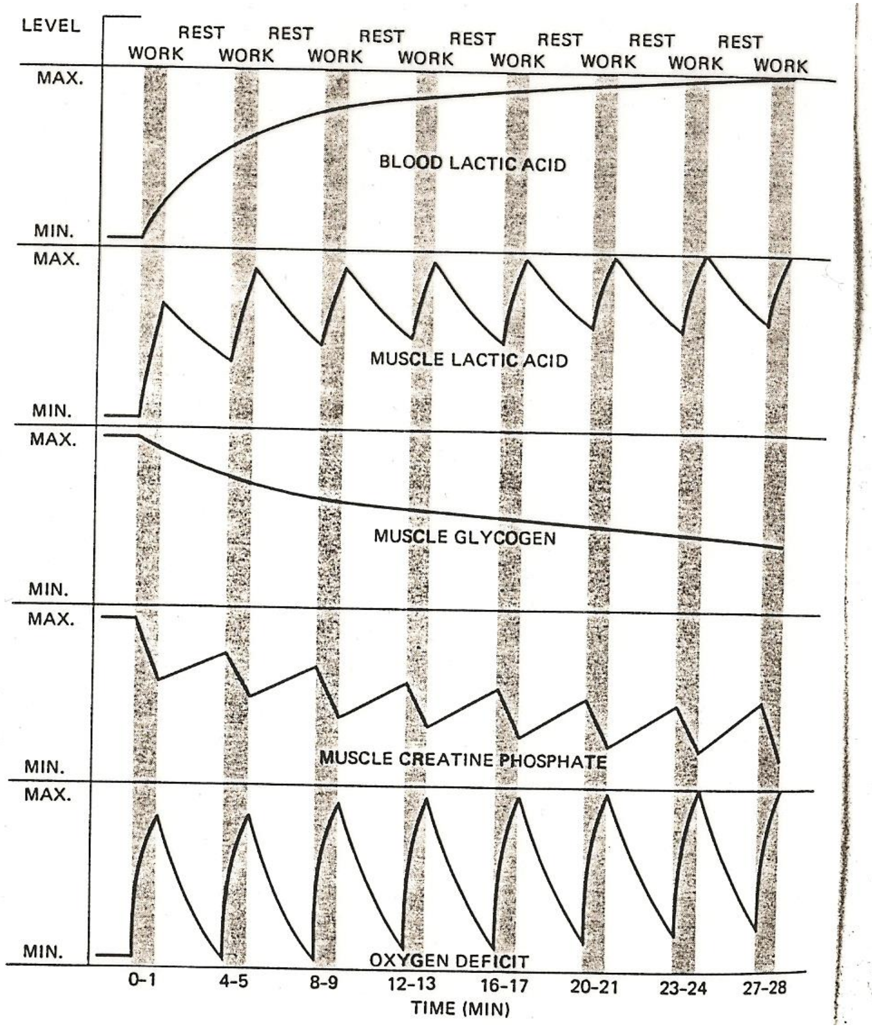
Interval Training

Suggested Interval Training: Work to Recovery Ratios

Sport	*Work Interval of High Intensity*	*Recovery – Submaximal Interval*
Football	20 – 30 sec.	60 – 90 sec.
Basketball	20 – 30 sec.	60 – 90 sec.
Baseball	40 sec.	90 sec.
Soccer	30 sec.	60 – 90 sec.
Hockey and Ringette	30 – 40 sec.	60 – 90 sec.
Lacrosse	30 sec.	60 – 90 sec.
Speed Skating (short distance)	40 sec.	90 sec.

Work load should be 90% of maximum effort during high intensity interval

Lactate, Glycogen and Oxygen Levels During Interval Training



Substrate Utilization and Rate of Replenishment:

- Max bursts (15 secs followed by 15 sec recovery), the CP stores are replenished to ~80% of starting value by 15 seconds.
- If continue this routine for 4-6 mins, it takes 3 mins to replenish 50% of CP starting values, as build of lactic acid inhibits glycolysis and fatty acid metabolism, thus less ATP available for CP synthesis
- With repeated bouts of 1-2 min max bursts (hockey shift, 800 meter sprints, 200 meter swims, cycling sprints), there is replenishment of ATP and CP during rest interval from the up-regulated oxidation of muscle glycogen, and to a lesser degree, blood fats and blood glucose (CP synthesis is energy dependent)

- Repeated max contraction of thigh m. for 1-6 mins results in total depletion of CP. CP is 50% replenished in 30 secs, but requires 7 mins for 95% replenishment

- Heavy Exercise For Between 2 and 40 MINS (10 km run, 400-2,000 meter swim, 1,500 meter run) – Primarily glycogen dependent (only 10-20% of ATP from fatty acid oxidation, but post-exercise partitioning of fuels favors continued fat burning while glucose and glycogen are being re-synthesized)

- Heavy Exercise For 40-150 MINS (half marathon) – 25% fatty acid contribution to ATP synthesis at 150 mins. The primary fuel is derived from the aerobic metabolism of muscle glycogen (rate-limiting) and blood glucose

- Heavy Exercise For More Than 150 MINS (marathon) –Fatty acid oxidation at 1 hr mark is 20%, at 4 hrs is 50%, with the balance of energy from the oxidation of m. glycogen and blood glucose (recall that protein catab also occurs and provides 2-10% of energy during this period)

- Light Exercise (continuous occupational walking or work at a machine station for 8 hrs) –Fatty acid oxidation is 20-50% of ATP synthesis in first 4 hrs, and 90% contribution in the eighth hr if no food consumed (e.g. Postal route, or sewing machine operator) – Muscles prefer burning fat when at body at rest or during light activity. Blood glucose used by brain, nervous system, hepatic cells etc. Very little blood glucose or m glycogen burned by skeletal m under these circumstances.

As such, light activity does not deplete m. glycogen, which is barely utilized under these conditions even in fasting state. **Patients with Glycogen-storage defect diseases** can perform these activities even though they have no glycogen stores.

- Reference: The Physiology of Exercise (second edition). D. Lamb. Macmillan Publishing Company.1984

Glycogen Storage Diseases

In United States, glycogen storage diseases occur in 1 per 20,000-25,000 births

Examples of Glycogen Storage Diseases

- von Gierke's disease
- Pompe's disease
- Cori's disease or Forbes' disease
- Andersen disease
- McArdle disease

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Subsection 2: Macronutrients and Nutrient Utilization

- CHO
- Protein
- Fat
- Basal Metabolic Rate, METs, Caloric Needs
- Nutritional Strategies (day-to-day, pre-competition, during competition, post-competition, etc.)

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Carbohydrate Ingestion And Performance

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Carbohydrates and Endurance Performance

- **Depletion of muscle glycogen leads to fatigue**

- **Relative contribution of CHO to energy production determined by:**
  - Exercise intensity (below 3.7 cal/kg/hr, **mostly fat burn**) – 162 cal/30 mins in my case (87.7 kg or 193 lbs)

  - Exercise duration (increased fat burning over time)

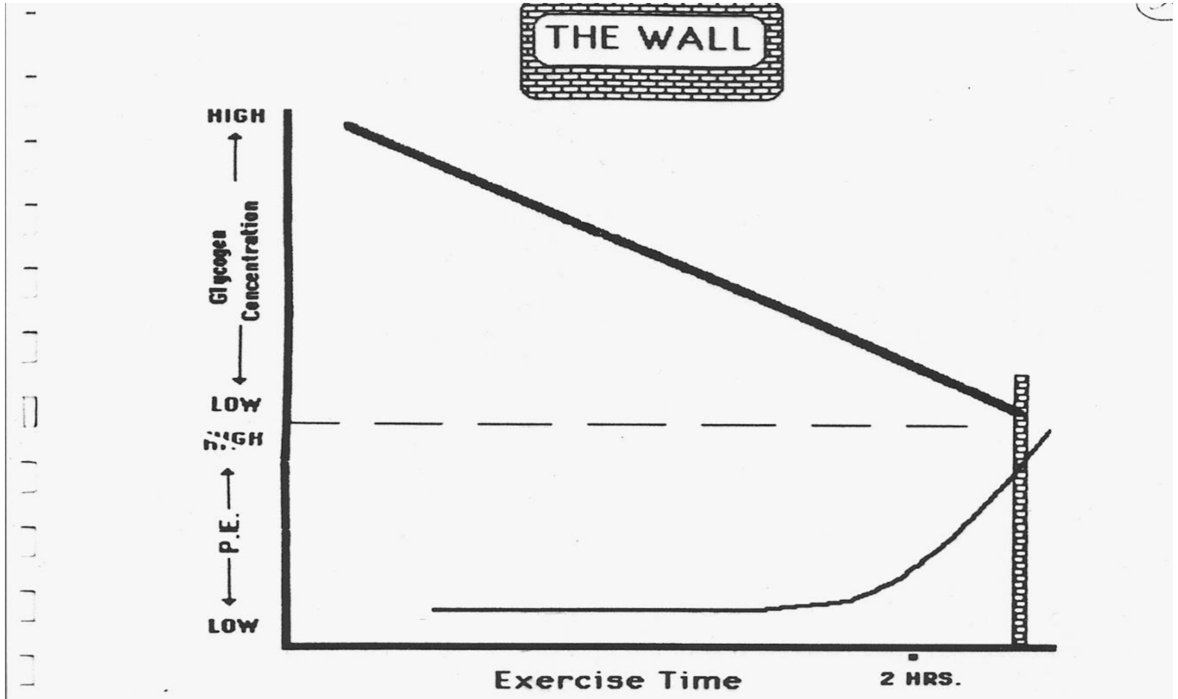
  - State of physical training (more fat burning at any given work load with increased conditioning)

  - State of Health (diabetics resist CHO burning)

- Muscle Glycogen is vital substrate at 70-80% of VO2 max- (most endurance events)

- Thus, initial m. glycogen stores play a significant role in endurance performance (glycogen depletion slows pace)

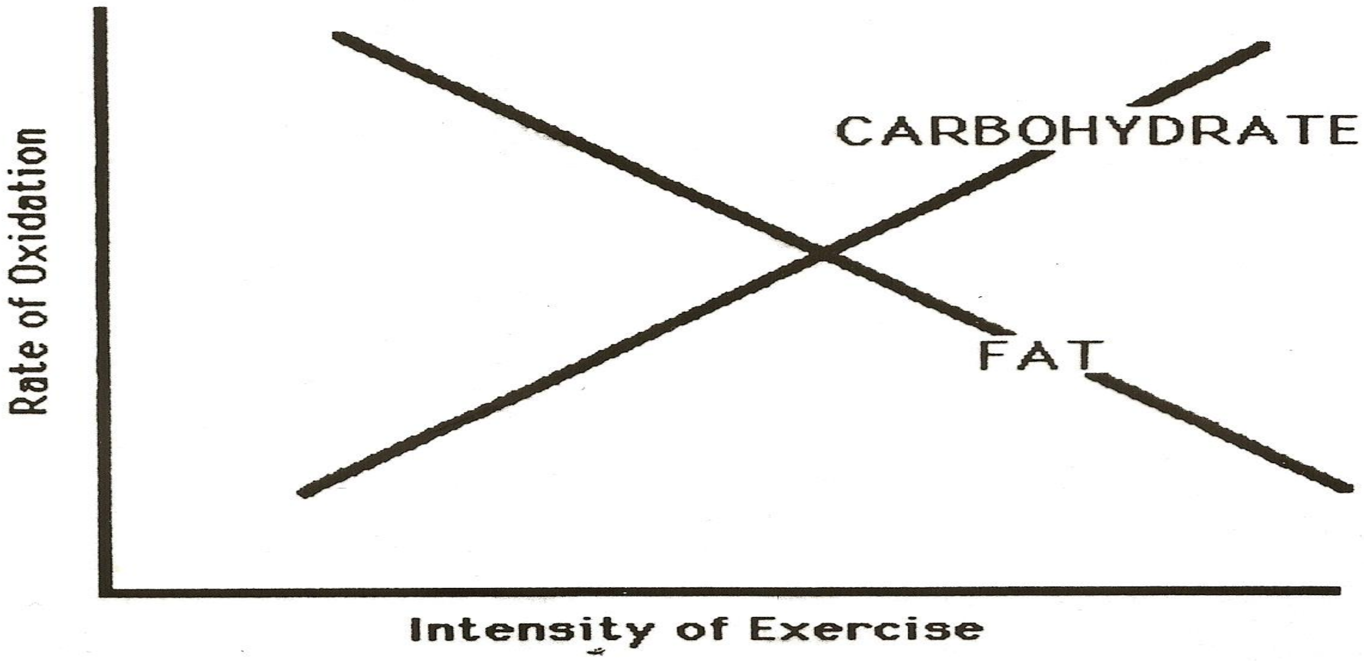
Glycogen Depletion/Hit The Wall



- As muscle glycogen concentration becomes depleted, the perceived exertion remains constant, until glycogen stores become very low.
- The perceived exertion increases dramatically when glycogen concentration reaches critically low levels.

GLOBAL INTEGRATIVE MEDICINE ACADEMY

Exercise Intensity and Fuel Utilization: As CHO can generate ATP anaerobically as well, CHO utilization increases with intensity, especially above anerobic threshold level.



- Depletion of liver glycogen leads to hypoglycemia (dizzy)

- Exercising m. extracts glucose from blood stream at a rate up to 30-40X greater than at rest

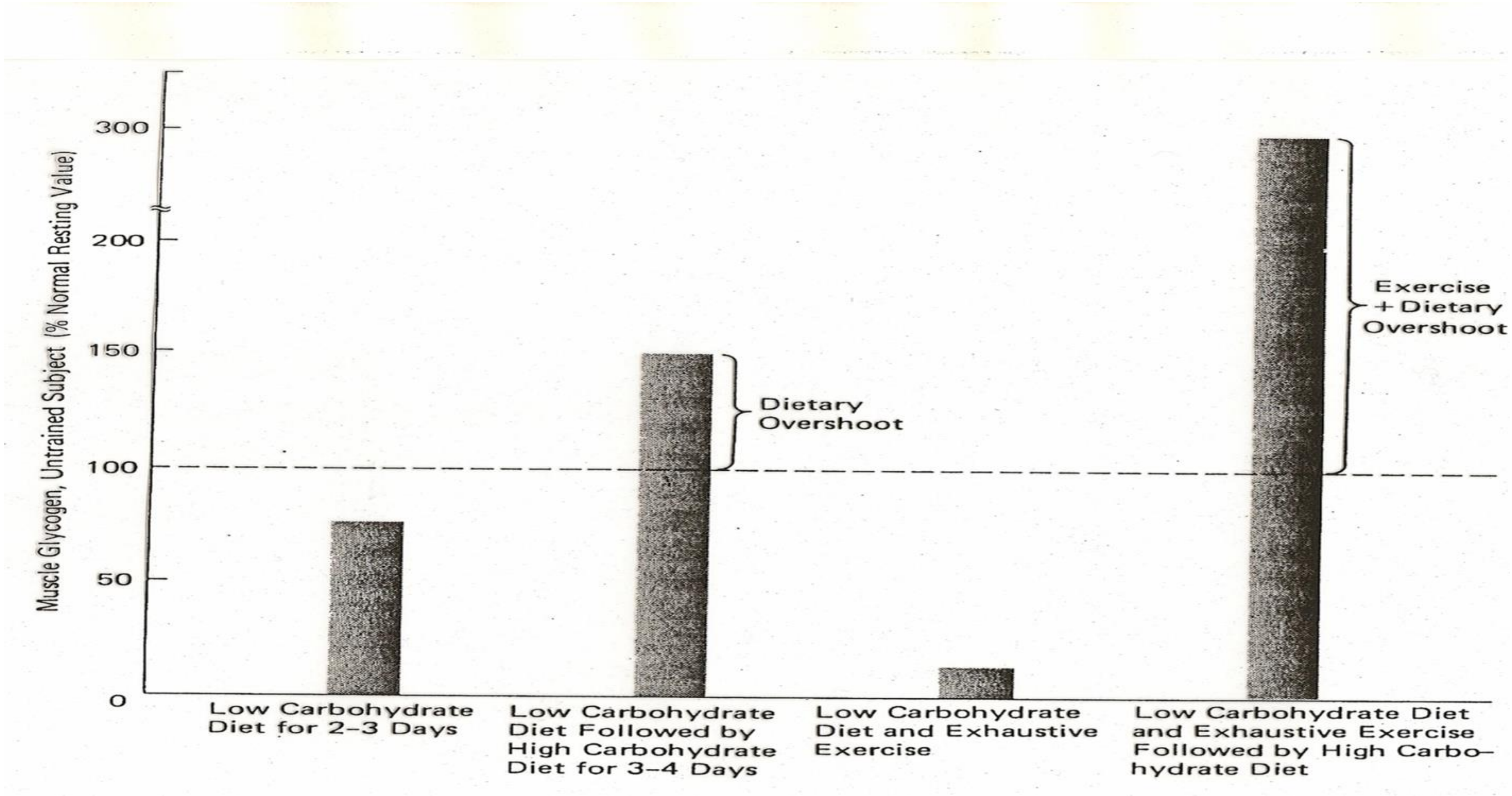
Day-to-Day CHO Strategy

- CHO should comprise 60-70% of caloric intake for endurance athletes (max of 20% of CHO from refined sugars, 80% starches and complex CHO)
- May require up to 4.5 gm of CHO per pound of body weight, per day – depending upon training intensity and duration (e.g., 200lbs x 4.5 gm = 3,600 cals per day CHO)
- Running athletes burn as many calories per km as they weigh in kg (run 10 km - burn 700 cals, if weigh 70 kg)

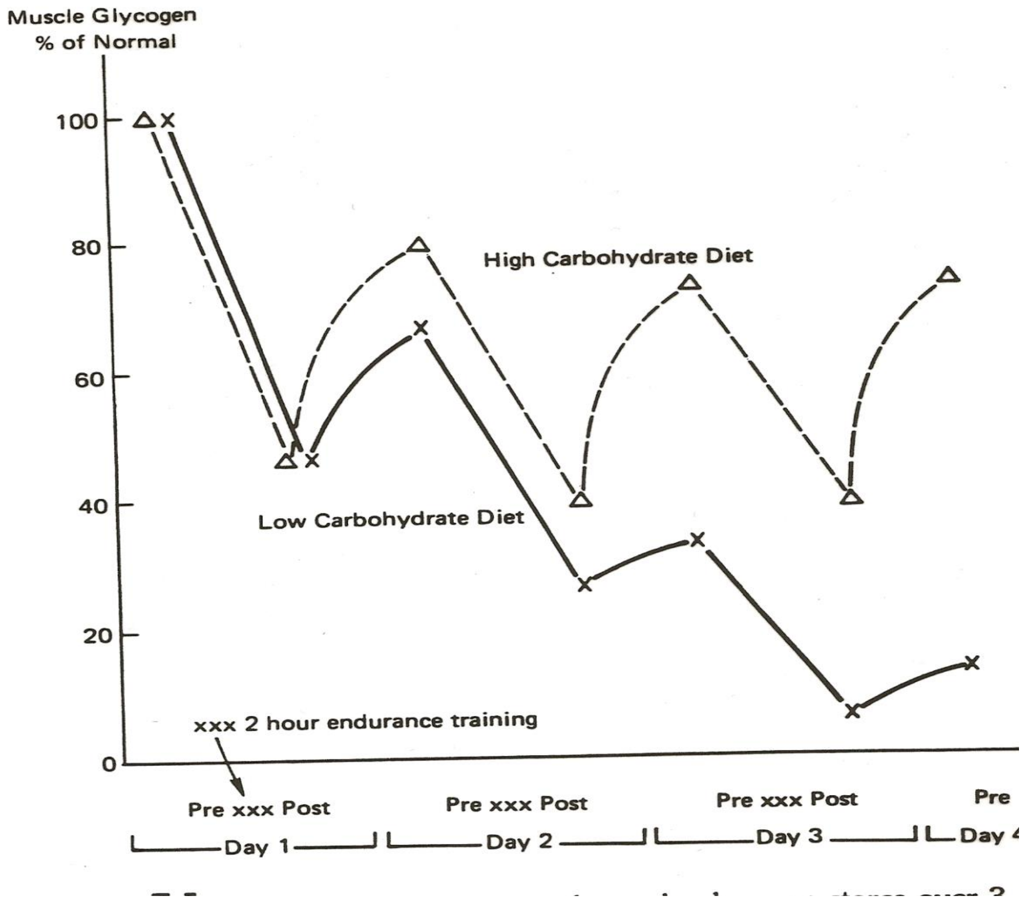
Carbohydrate Loading Can Increase M Glycogen 200% (steps):

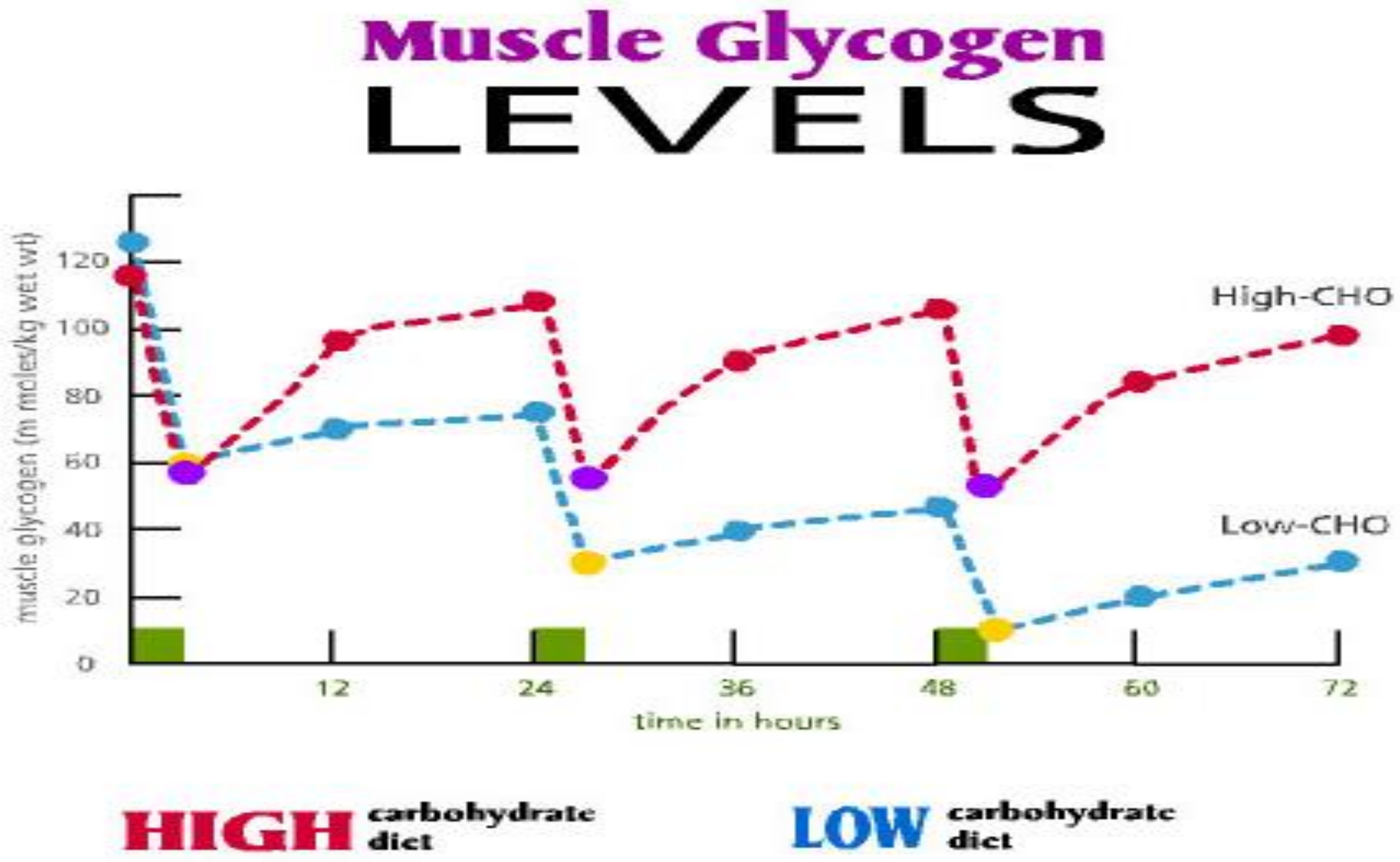
1. 6-7 days prior to competition – consume a very low CHO diet for 2-3 days
2. 3-4 days prior to competition athlete works muscles to exhaustion (glycogen depletion)
3. 1-2 days prior to competition consume CHO-rich diet, with light training
4. No training at all on day prior to competition (glycogen repletion takes minimum 24-hrs)

Glycogen Loading



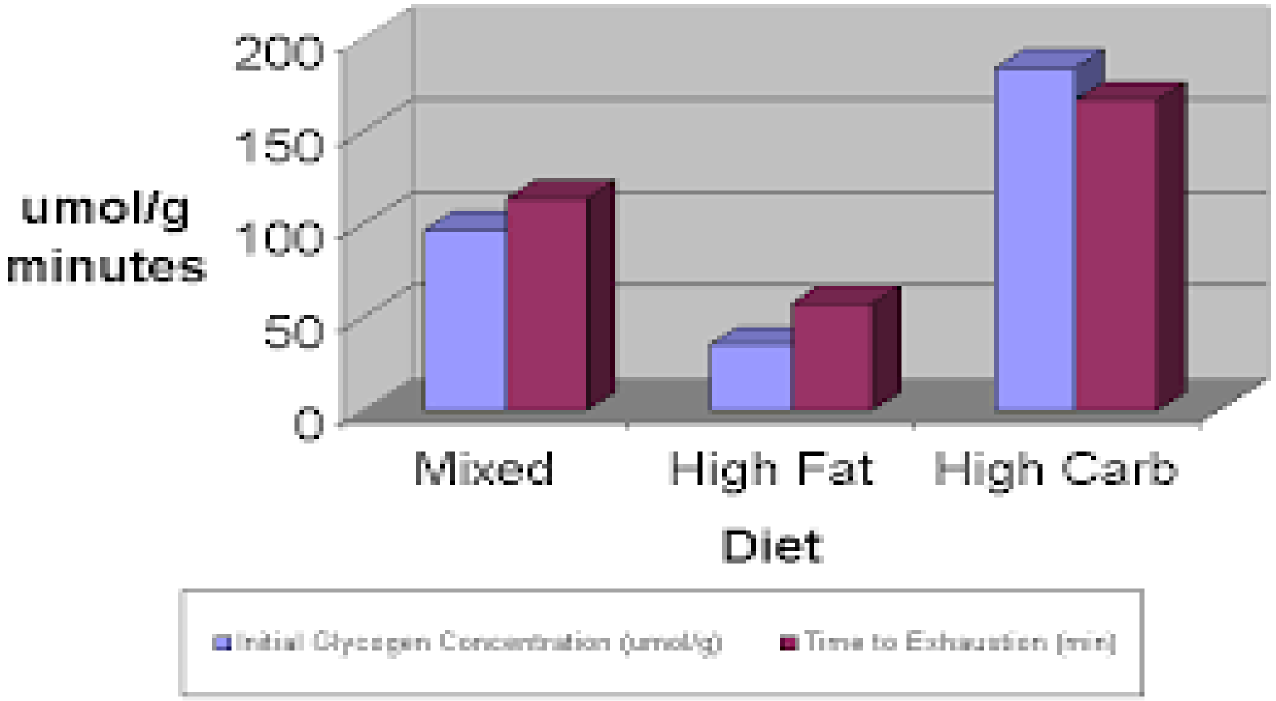
High vs Low CHO Intake




Muscle Glycogen
LEVELS
muscle glycogen (m moles/kg wet wt)
120
100
80
60
40
20
0
12
24
36
48
60
72
time in hours
High-CHO
Low-CHO
HIGH carbohydrate diet
LOW carbohydrate diet

GLOBAL INTEGRATIVE MEDICINE ACADEMY

Blue= Initial Glycogen Concentration
Purple = Time to Exhaustion



Drawbacks to CHO Loading:

- 1. CHO are wet carbon atoms (CH_2O), weight gain of 1-2 kg can occur
- 2. Increased CHO fuel can cause muscle stiffness

But CHO breakdown releases water, which helps prevent dehydration

- Optimal Muscle Glycogen is only a factor in endurance events lasting more than 40 mins – don't need major CHO loading routine for 10 km run.

CHO Intake 2.5 To 3.5 Hrs Prior To Competition

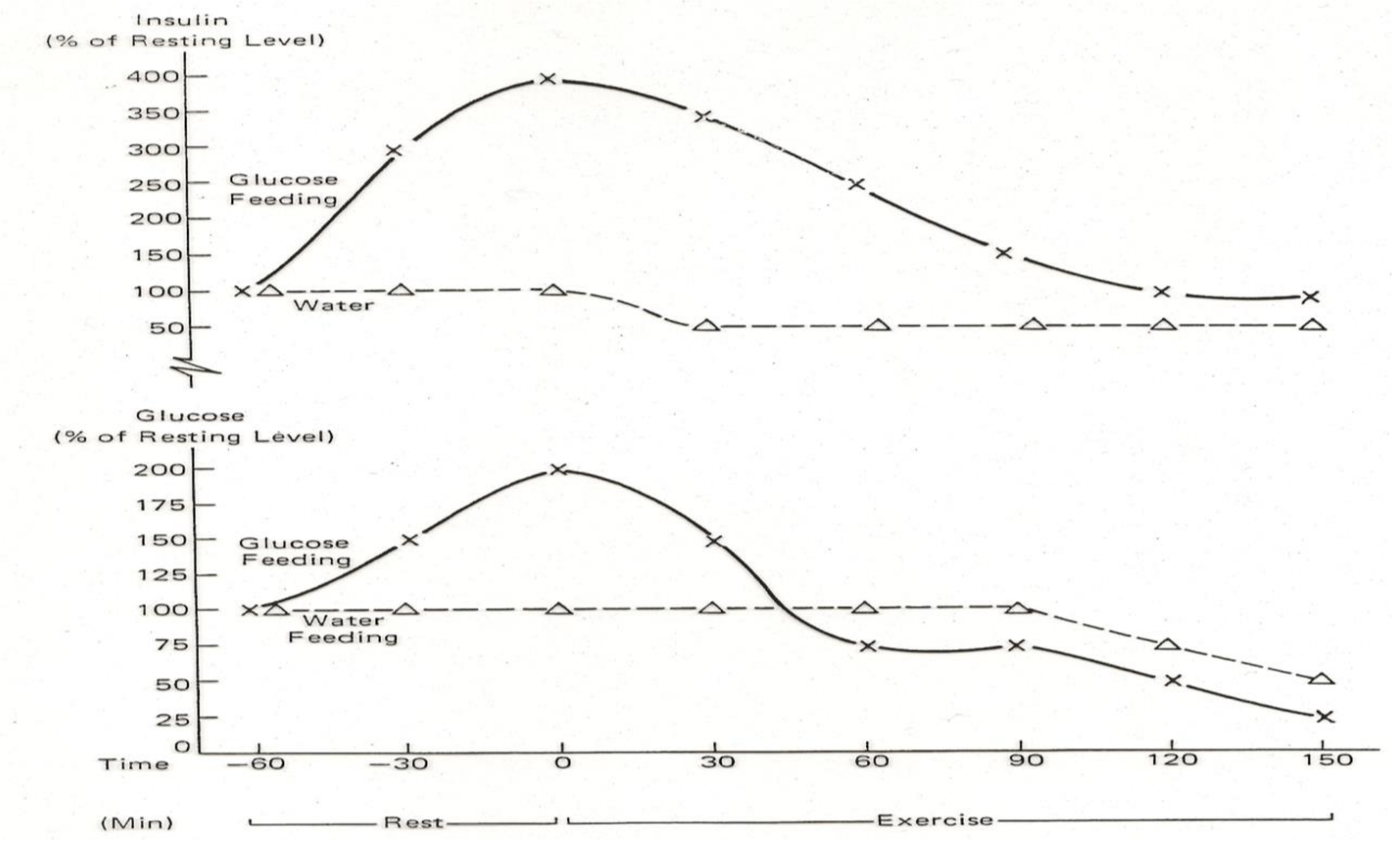
- CHO ingested any sooner than 2.5 hrs before competition hinders performance because, unless in Glycogen Depleted State (Tournament Days, or Competition Weekends)
  - 1. It takes 2.5-3.5 hrs for insulin levels to return to normal
  - 2.If insulin levels elevated when exercise begins get hypoglycemia within 60-90 mins as all cells clearing glucose rapidly from blood
  - 3. Exercise increases insulin sensitivity (hypoglycemia effect)

- However, if glycogen stores depleted prior to exercise then some CHO ingestion may be beneficial to reload m. and liver glycogen

- **Tournaments and Track Meets:**
  - Between same day games, practices or heats, ingest simple CHO to replenish m. and liver glycogen
  - Fat consumption slows gastric emptying (chocolate bars and milk shakes are bad; low fat granola bars, low-fiber fruits, fruit juices are good)

- 312 gm CHO (1,248 cals) consumed 4 hrs prior to strenuous endurance exercise increased performance by 15% - no change seen with 45 or 156 gm

Glucose and Insulin Response to CHO vs Water Ingestion (Insulin Sensitivity Effect)



CHO Intake Immediately Prior To Competition:

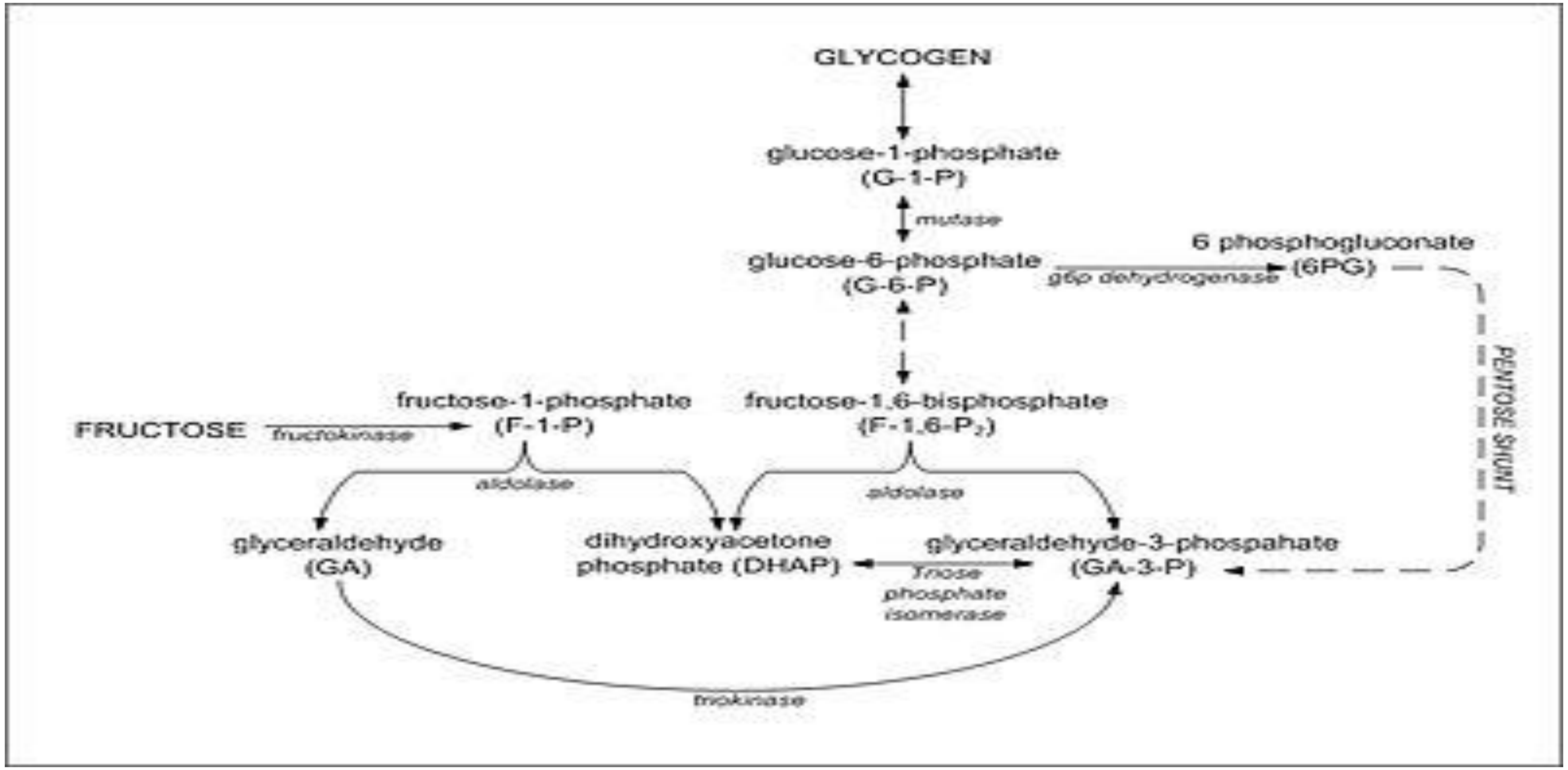
1. Three glasses of water (750 ml) containing 4% solution of glucose improved performance by 29% compared to athletes consuming three glasses of water with no glucose

- Why? Exercise causes a drop in insulin levels, so that glucose entering blood stream after exercise has begun has only a minimal effect on insulin secretion. The ingested glucose is used by muscles instead of muscle glycogen, thereby slowing m. glycogen depletion, which improves performance (29% improvement is highly significant)

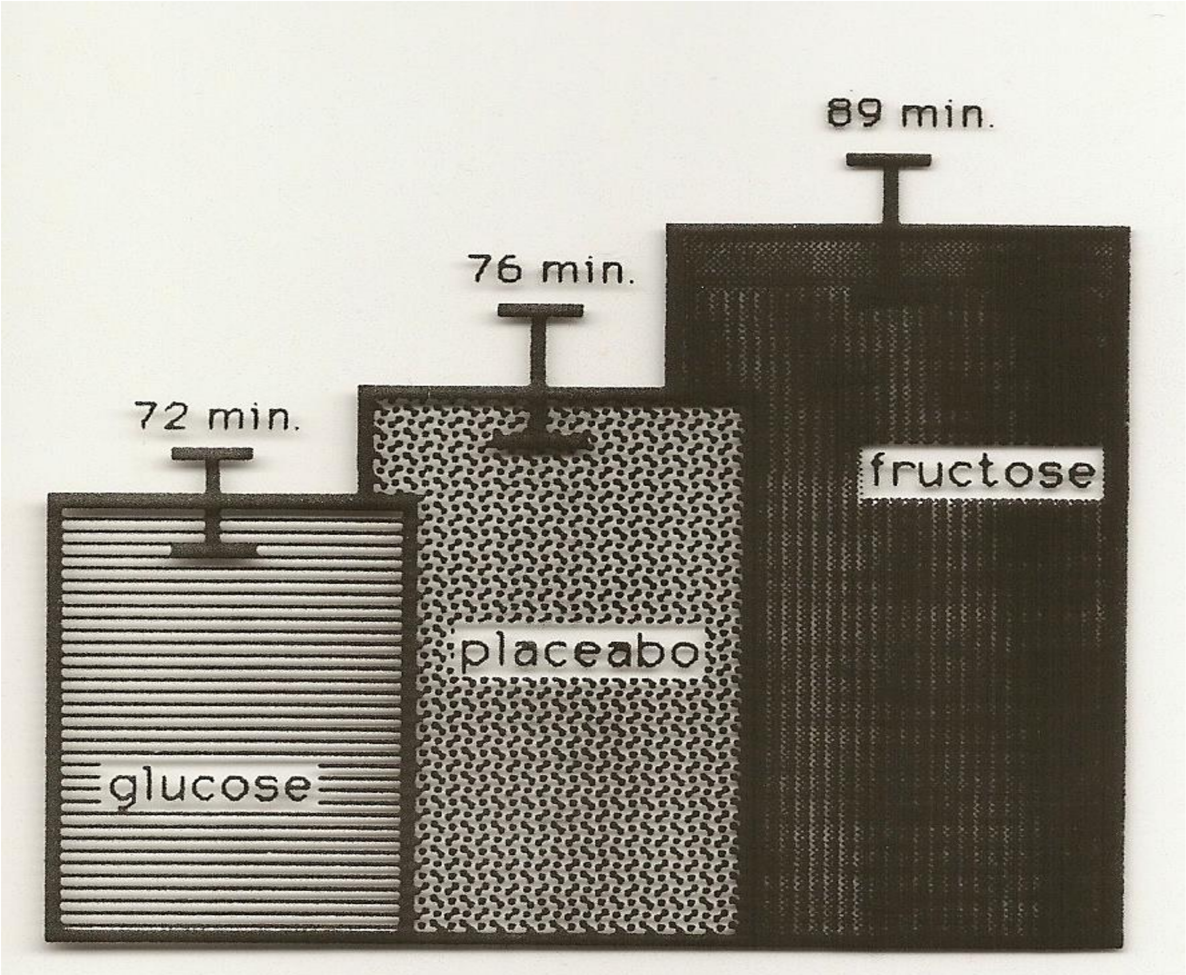
2. Alternatively, ingesting 20 gm of fructose mixed into 20-25 ounces of cold water, 30 mins prior to exercise, also improves endurance performance.

Fructose does not raise insulin levels as much as other sugars and provides an immediate source of CHO to the exercising muscle, which slows m. glycogen breakdown – enhancing performance

Fructose slowly converted to glucose with blunted insulin response



Fructose 30 Mins Pre-Exercise Enhances Endurance Performance (E. Price. Palmer Chiropractic College West – San Jose Cal)



CHO Intake During Endurance Exercise:

- Significant blood sugar decline occurs at 2 hours into endurance event (ht rate of 100-150 bts/min)-hit the wall
- Up to 25% of the CHO oxidized during exercise comes from CHO consumed during exercise (prevents hypoglycemia and slows m. glycogen depletion)
- Breakdown of CHO during endurance exercise occurs at 1-1.5 gm per min, thus replenishment of 30 to 70 gm CHO per hour is recommended

- This is achieved by drinking 5-8 ounces of a sports drink, every 10-15 mins, after the first 30 mins of event.

- Sports drinks contain 6-8% solution of simple CHO and/or glucose polymers (beyond 10% slows gastric emptying, increased osmolarity – diarrhea, cramps and reduced H_2O absorption to bloodstream – risk of dehydration)

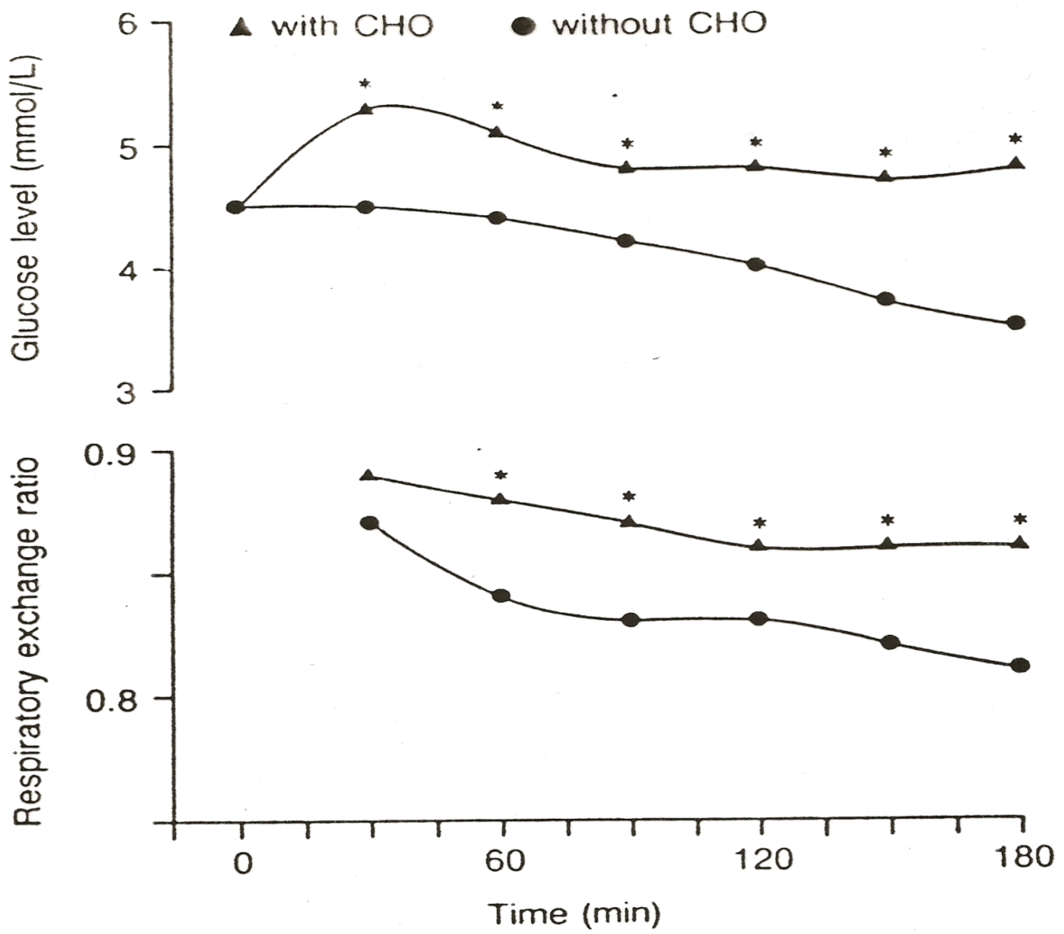
- Sports drinks only of benefit in endurance events lasting more than one hour – so best to drink only water for first hour.
- Glucose polymers are less sweet and touted to be more palatable than simple sugars
- Cold water (5 degrees C) is absorbed twice as fast as water at room temperature (but questioned lately)
- Consuming sports drinks in the first 30 mins of exercise can inhibit fat mobilization by raising insulin levels, thus it is best to wait for at least 30 mins into event

Carbohydrate Replenishment Drinks vs Sodas and Soft Drinks – 12-14% CHO Concentrations

Drink	Carbohydrate (g/100ml)	Minerals (mmol/L)
'Body Fuel 750' (USA)	7.5-glucose polymer, fructose	Sodium 12 Potassium 2
'Exceed' (USA)	7-glucose polymer, fructose	Sodium 10 Potassium 5
'Gatorade' (USA)	6-sucrose, glucose	Sodium 23 Potassium 3
'Isostar' (Europe)	7.5-sucrose, glucose polymer	Sodium 24 Potassium 4
'Maximum' (Australia)	7-glucose polymer	Sodium 10 Potassium 5
'Replace' (New Zealand)	8-glucose, fructose, glucose polymer	Sodium 10 Potassium 5
'Staminade' (Australia)	4-glucose	Sodium 10 Potassium 5
'Suntory' (Japan)	6.5-sucrose, glucose	Sodium 12 Potassium 5

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

CHO Replenishment and Respiratory Exchange Ratio



Respiratory Quotient

The ratio of carbon dioxide produced to oxygen consumed is termed the RQ.

The RQ for CHO oxidation = 1.0

The RQ for Fat oxidation = 0.70

The RQ for Protein oxidation = 0.82

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Insulin and CHO Response To CHO Drinks vs Water (Hypoglycemia)

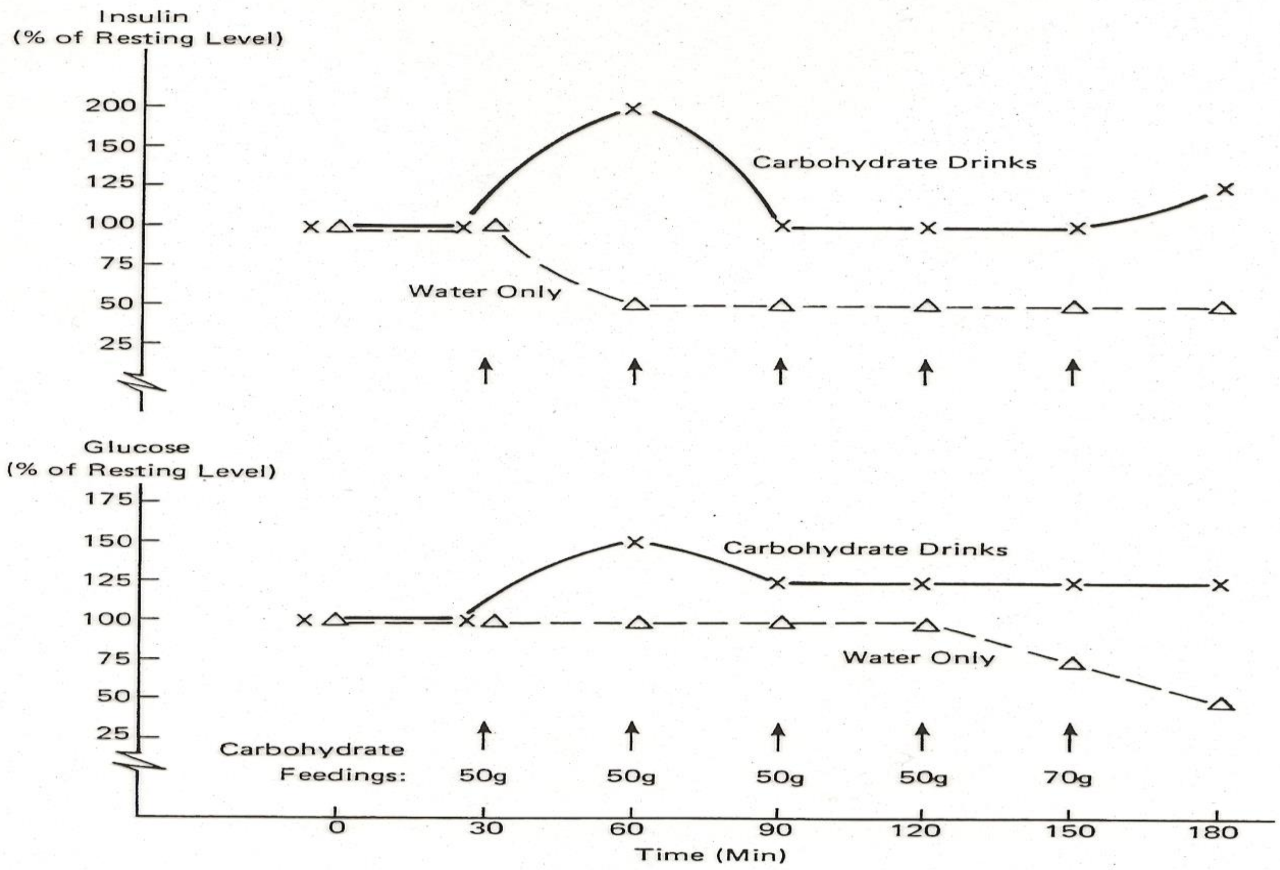
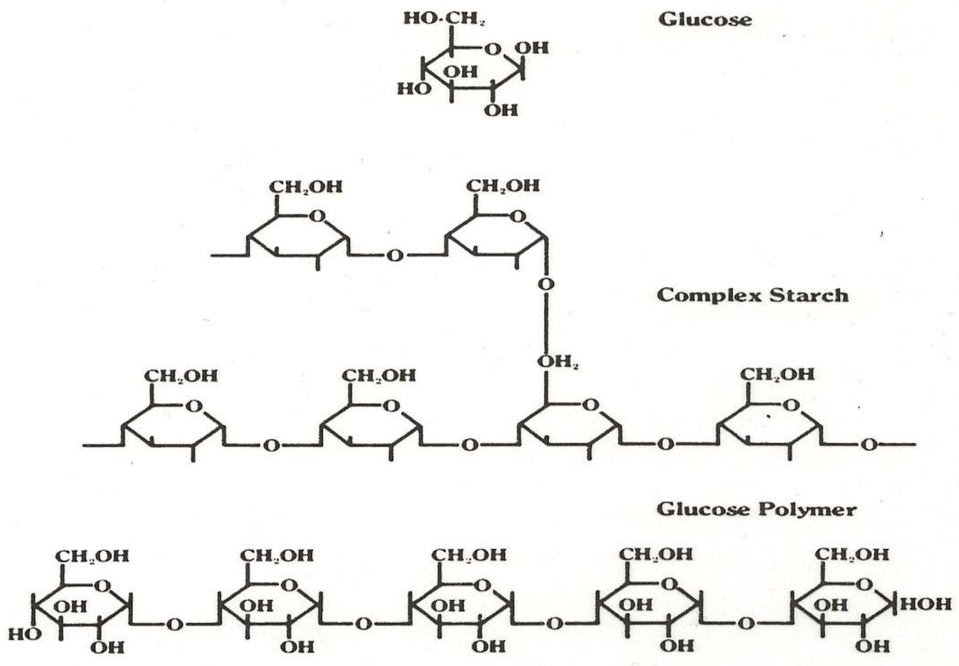


FIGURE 5.7. Effect of carbohydrate feedings at 30 minute intervals during prolonged exercise at heart rates of 150–160 beats per minute.

Glucose Polymers

Glucose polymers may be a better carbohydrate source for fluid replacement beverages. A glucose polymer is larger than the short-chain sugars but smaller than the complex starches (Fig 11). If glucose polymers rather than free glucose or sucrose are in the beverage, more carbohydrate could be delivered to the gut without having a hypertonic solution.



Post-Endurance Exercise Carbohydrate Repletion:

- 40-60 gm (160-240 calories) of CHO should be consumed immediately post exercise (sports drinks and other simple CHO)

- In the first two hours post exercise glycogen synthase enzyme is very active and glycogen repletion can occur quickly if CHO feeding is implemented

- The most ideal way to restore glycogen stores is to consume 50 gm (200 cals) CHO every 2 hours for 20-24 hours post exercise (e.g., three day tournaments)

- Good food choices include sports drinks, low-fat sports bars, pancakes, bread, rice pasta, potatoes, fruit, fruit juices sweet vegetables etc.

- Exercise also causes protein catabolism, which should be addressed (GH release plus insulin facilitates protein synthesis post exercise - need CHO ingestion)

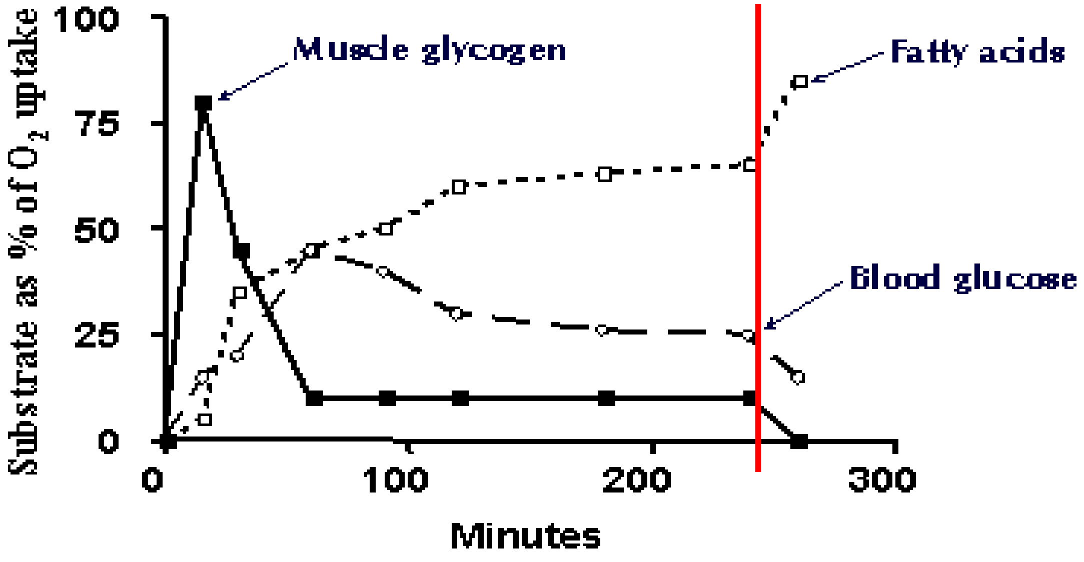
Updated CHO Facts and Considerations - Reference 1

- CHO is only macromolecule that can generate ATP anaerobically (in cytosol of cell via glycolysis)
- During light and moderate aerobic exercise, CHO supplies about 1/3 of body's energy requirement
- Aerobic breakdown of CHO is faster than fat, and thus generates ATP energy more quickly. Once glycogen depletion approaches ATP synthesis slows
- CHO depletion depresses exercise capacity. This capacity progressively decreases after 2 hours to 50% of the initial exercise intensity. Reduced power directly results in relative slow rate of aerobic energy release from fat oxidation, which now becomes the major energy pathway.

GLOBAL INTEGRATIVE MEDICINE ACADEMY

Energy Sources in Working Muscle

Exercise duration and choice of substrate



- Symptoms of significantly reduced blood glucose (severe) hypoglycemia kick in once blood glucose drops to less than 45 mg/dl (2.5 mmol/L). Symptoms include: weakness, hunger, and dizziness – can proceed to unconsciousness at this point.

Some Numbers as Yard Sticks:

- Healthy Fasting Blood Glucose = 4.0 – 4.7 mmol/L – (72-85 mg/dL)
- Acceptable Fasting Blood Glucose= 4.7 – 5.0 mmol/L (72-90 mg/dL)
- Early Elevation of Fasting Blood Glucose= 5.0 – 5.5 mmol/L (90 – 100 mg/dL)
- Prediabetes 5.7 – 6.7 mmol/L (103 -125 mg/dL)
- Diabetes -7.0 mmol/L (126 mg/dL)

- One hr of intense exercise depletes liver glycogen by about 55% and 2 hours pretty much depletes all liver glycogen.

- Muscle uptake of glucose increases as exercise time progresses and is 7-20 times the resting uptake by the 40-minute mark.

- Muscle and liver glycogen combine to provide about 50% of energy in working skeletal muscle by 20-minute mark of intense exercise with fat contributing almost the other 50% - 20% of that is from breakdown on intramuscular fat and 30% is arriving from adipose tissue. At lower intensity fat contributes significantly more to ATP synthesis and at higher intensities CHO contributes more.

- With training a key adaptation is the skeletal muscle can rely more on fat-burning with less liver and muscle glycogen depletion, which slow CHO depletion and extends high performance time – increased fat-burning oxidative enzymes – succinate dehydrogenase etc.

- Women tend to continue burning more fat at end of exercise session than do men. Reason is unknown but estrogen and progesterone may influence lipolysis rate or other factors.

- During 90 minutes of strenuous exercise blood glucose can drop to serious hypoglycemic range- below 45 mg/dL.

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

- The Nervous System requires (CNS) uninterrupted stream of CHO to function properly. Brain uses glucose almost exclusively under normal conditions. In uncontrolled diabetes, fasting or low CHO state the brain switches to ketone burning primarily after about 7-8 days.

- Multiple sets of single exercises can reduce a muscle's glycogen content by 40%.

- CHO Requirement – should range between 6-10 gm/kg depending upon energy expenditure (6 x 90 = 540 gm or 2,160 cals CHO per day in my case) or if really active 10 x 90 = 900 gm or 3,600 cals CHO per day in my case)

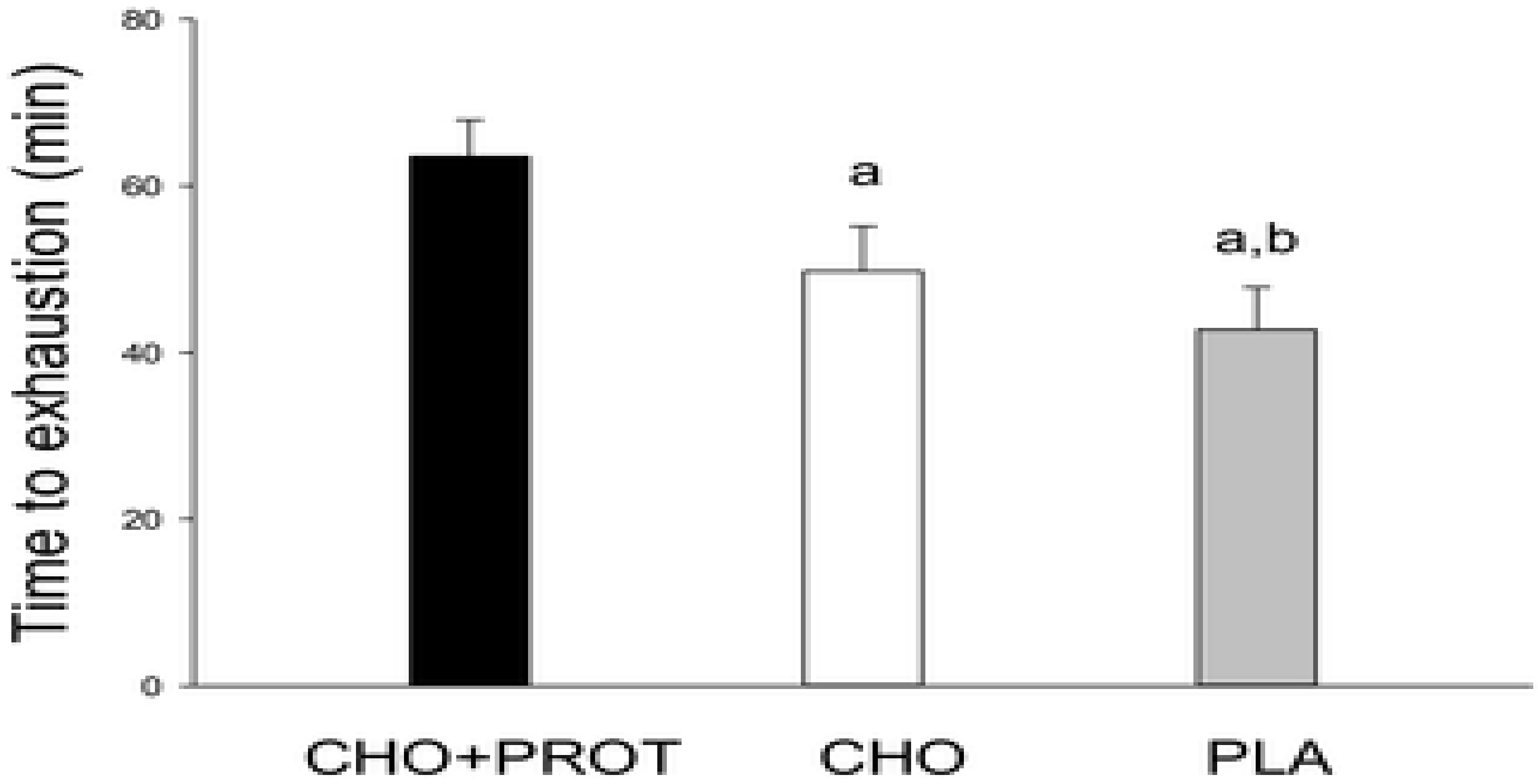
- It takes 24 hours to replenish muscle glycogen following prolonged exhaustive exercise; liver glycogen replenishes faster.

- One-to-two days of rest (or lighter exercise) combined with a high-CHO intake re-establishes pre-exercise muscle glycogen levels after exhaustive training or competition.

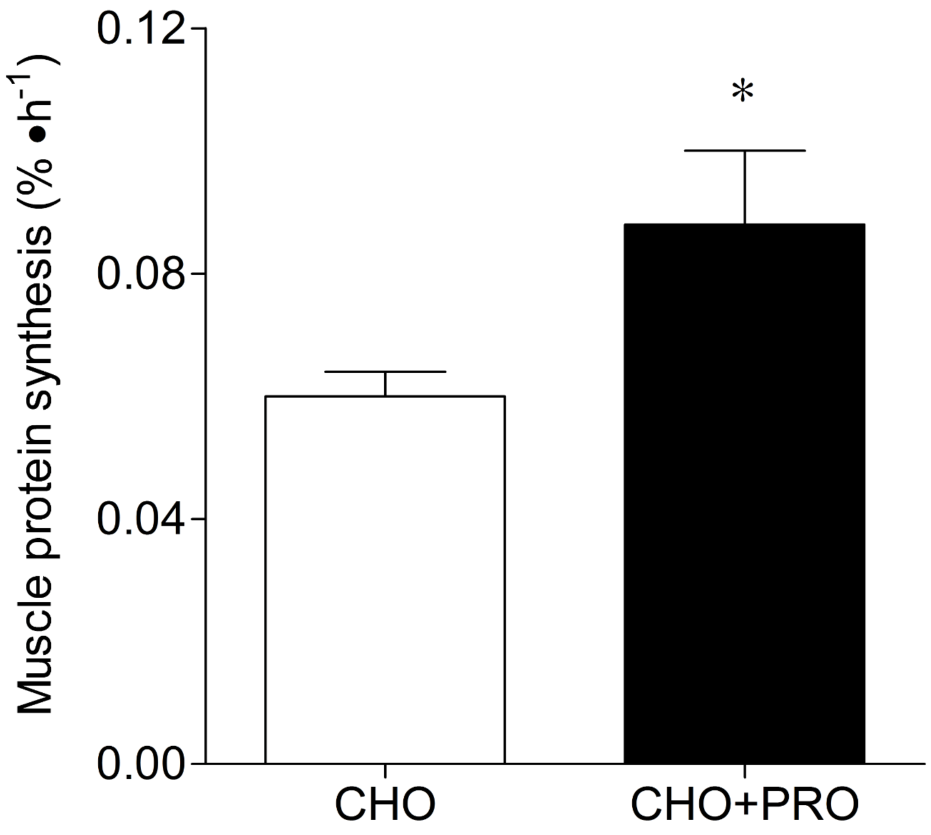
- New Research Show that Combining CHO with Protein is more effective at replenishing Glycogen Stores than CHO alone and Enhances Muscle Protein Synthesis better than protein alone (see next slides and reviewed in more detail in Protein subsection)

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

CHO plus Protein Improves Time to Exhaustion



CHO + PRO Best Effect on Muscle Protein Synthesis



GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Liver Glycogen (Modern Nutrition in Health and Disease 10th edition

- Liver glycogen stores depleted after 12-18 hours of fasting
- Liver capacity is about 90 gms and total muscle glycogen capacity about 300 gms, and 30 gms of glucose in bloodstream at any given time.
- Creatine phosphate can help to resynthesize glucose during exercise with repeated sprint-like activities.
- Carb depletion occurs in 1-3 hours of activity depending on the intensity of the effort.
- Carbs prior to exercise:
- 3-4 hours before – 200-300 gm of carbs (800 – 1200 calories) – maximize maintenance of blood glucose

And/Or

- 1 hour before – 13-60 gm of carb (54 – 240 calories) – maximize maintenance of blood glucose
- After glycogen depleting exercise, carbohydrate intake of 200-400 gm (800 – 1600 calories) spaced over 4-6 hours after exercise aids glycogen repletion, but first two hours is critical as glycogen synthase is very active at this time.

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

- Alcohol produces hypoglycemia by increasing insulin secretion and the acetate formed from alcohol in the liver is released to the bloodstream and oxidized by body cells (like other ketones) preferentially over fatty acid oxidation. The body burns alcohol calories first.

- Alcohol also inhibits gluconeogenesis
  http://www.medicalnewstoday.com/releases/93141.php

- Alcohol also increases lipogenesis (converting carbs into fat)
  https://www.ncbi.nlm.nih.gov/pubmed/9815011
- http://www.jbc.org/content/277/32/29342.full

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Practical CHO Nutritional Guidelines for Prevention of Chronic Athletic Fatigue Among Athletes: P 235 (Reference 1)

1. Consume easily digested high-CHO drinks and solid foods 1-4 hrs before training/competition. Roughly 1 gm of CHO/kg body wt is recommended intake 1 hr before exercise, and up to 5gm-CHO/kg body wt at 4 hrs prior to exercise/competition.

2. Consume an easily digested high-CHO liquid or solid food containing at least 0.35-1.5 gm CHO/kg body wt immediately after exercise for the first 4 hours.

3 Consume a 15-25% CHO drink or a solid high-CHO supplement with each meal. For example, reduce consumption of normal foods by 250 kcal and consume a high CHO beverage of solid food containing 250 kcal of CHO with each meal.

4. Maintain a stable body weight during all phases of training by matching energy consumption to energy demands of training. This also helps maintain body CHO reserves

Overtraining Syndrome (Reference 1)

Not just fatigue but also:

- Increases risk of infection
- Injuries
- Persistent muscle soreness
- General malaise
- Loss of interest in sustaining high-level training

Symptoms are highly individualized, but these are Six Symptoms of Overtraining and Staleness:

1. Unexplained, persistent poor performance
2. Disturbed mood states, characterized by general fatigue, depression and irritability
3. Elevated resting pulse, painful muscles and increased susceptibility to URT infections and GI disturbances
4. Insomnia
5. Weight Loss
6. Overuse injuries

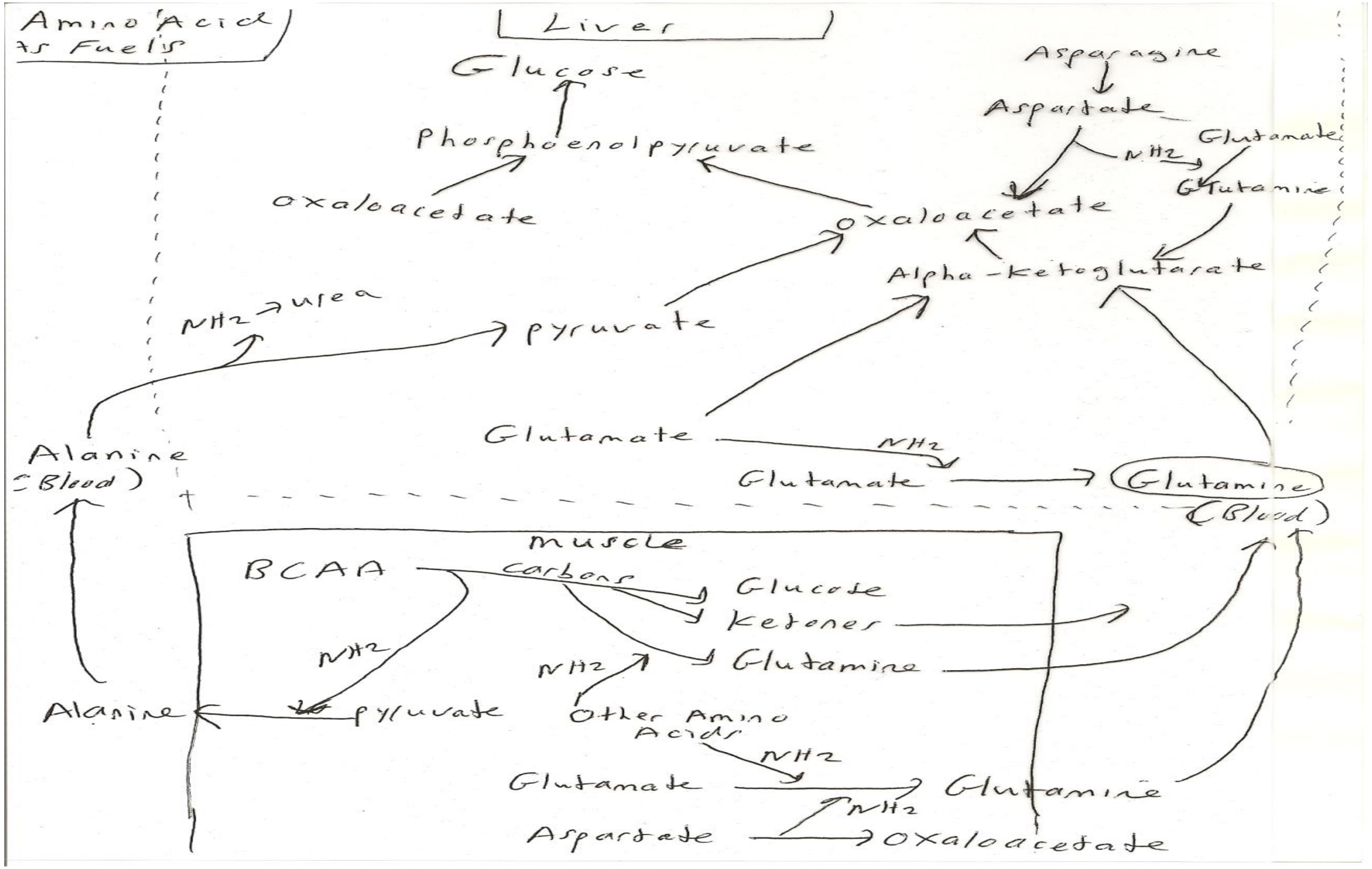
Protein and Exercise: Traditional Info

- 5-10% of energy derived from catabolism of m. protein

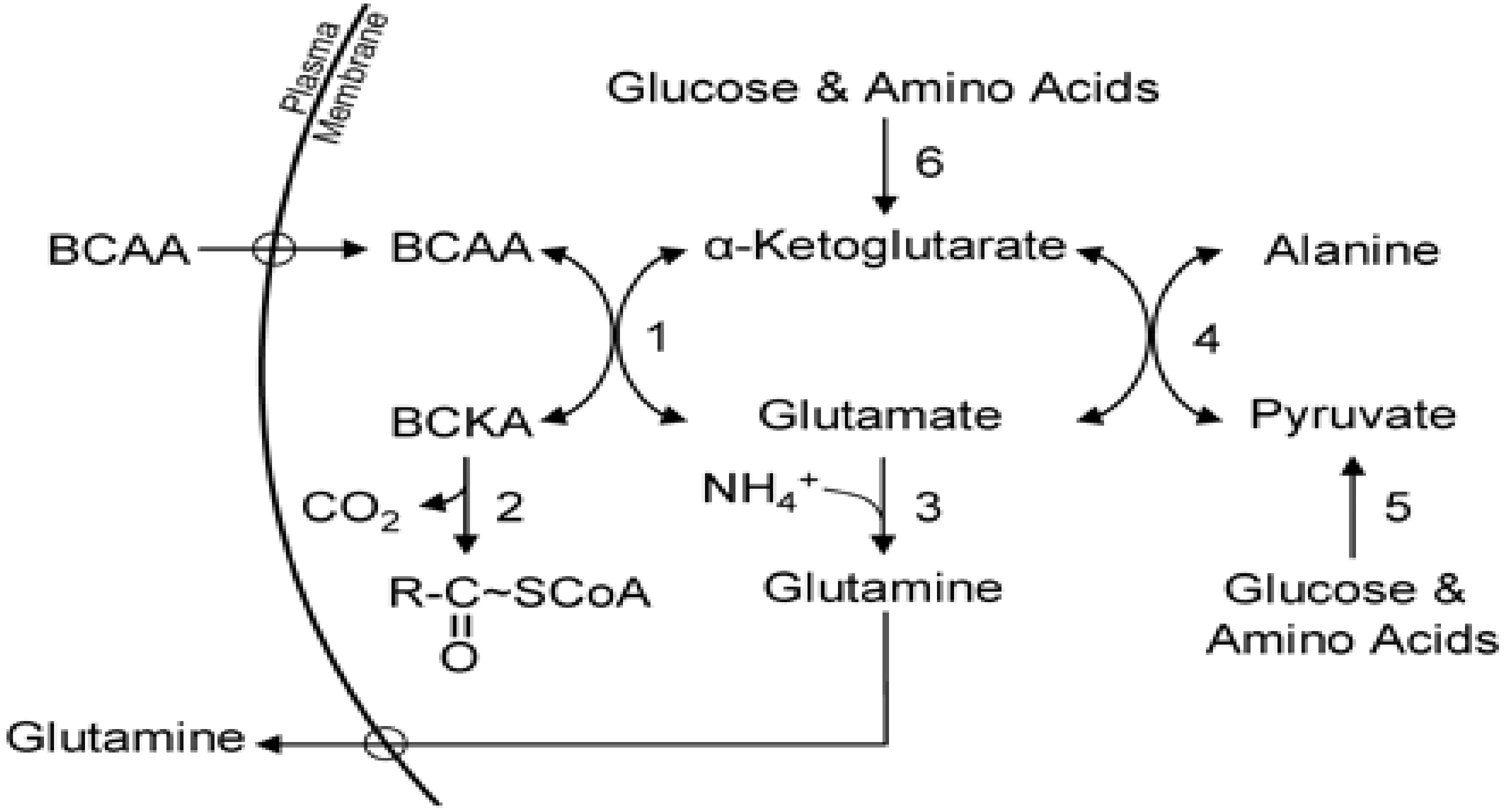
- Structural and non structural amino acids from muscle are catabolized to support gluconeogenic pathways as glycogen levels fall (prevents hypoglycemia even in fasting and uncontrolled diabetes)

- Branched-chain amino acids (leucine, isoleucine and valine) donate amide group (NH_2) to pyruvate to form alanine, which travels to liver. Once in liver alanine is converted to pyruvate, then to oxaloacetate, then to phosphoenolpyruvate, which can back peddle to form glucose. The deaminated amide group forms urea and is excreted in the urine

Alanine and Glutamine In Gluconeogenesis

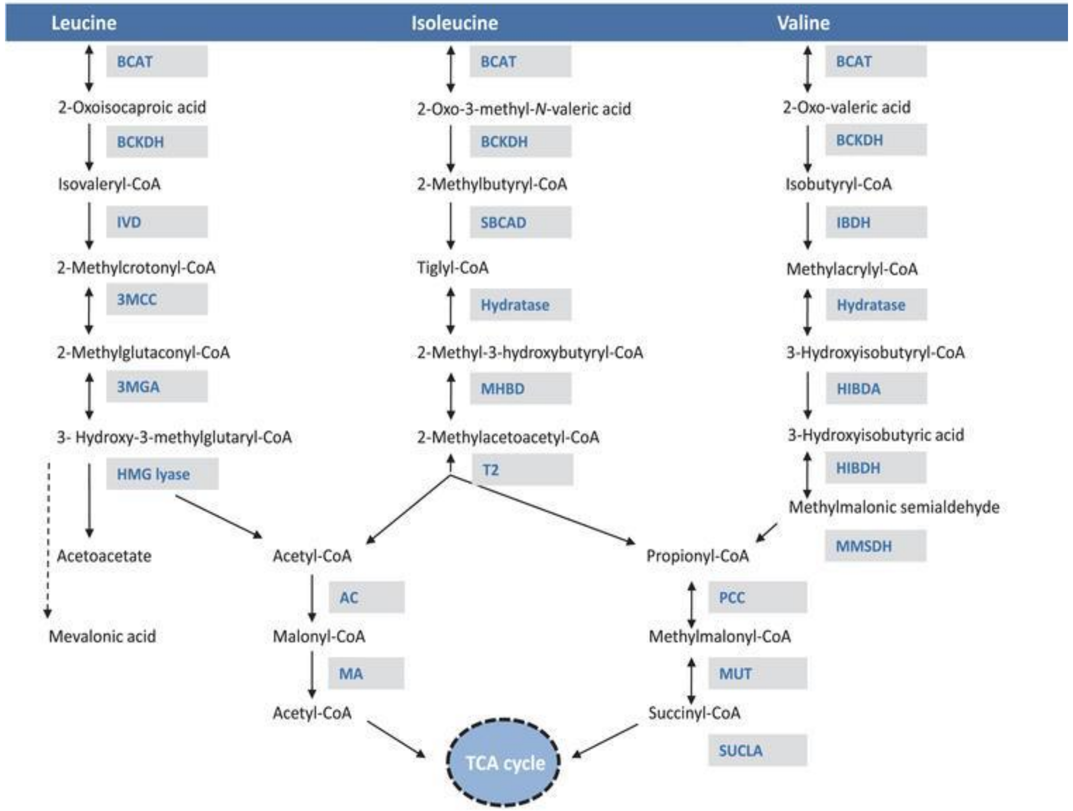


Synthesis of Glutamine and Alanine in Muscle



GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Branched-chain Amino Acid Metabolism



- The carbon backbone of branched-chain amino acids forms glucose, ketones or glutamine (these can be oxidized)

- Glutamine is also gluconeogenic. Once formed or arriving in the liver, glutamine is converted to alpha-ketoglutarate, then to oxaloacetate, then to phosphoenolpyruvate, which can back peddle to form glucose.

- The deaminated amide groups form urea. Thus , glutamine supplementation may slow the breakdown of branched-chain amino acids, (less alanine required to form glucose), which comprise 30% of the structural amino acids in skeletal m.

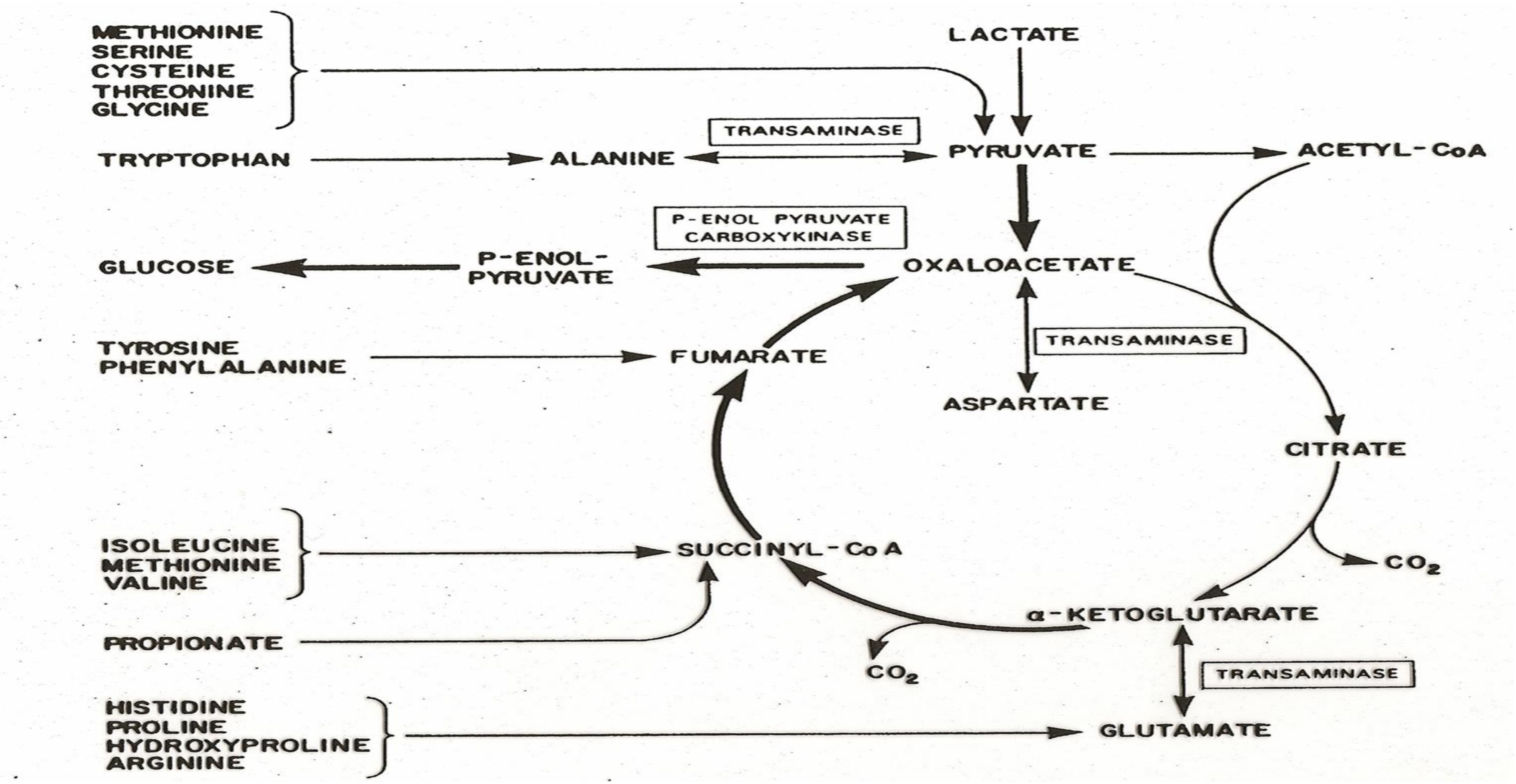
GLOBAL
INTEGRATIVE MEDICINE ACADEMY

- In hyper-catabolic states (burn victims, post surgery, AIDS, Cancer, Radiation Rx etc.), glutamine supplementation has been shown to be anti-catabolic – 2,000-4,000 mg per day –may benefit athletes. And provide energy for wound healing

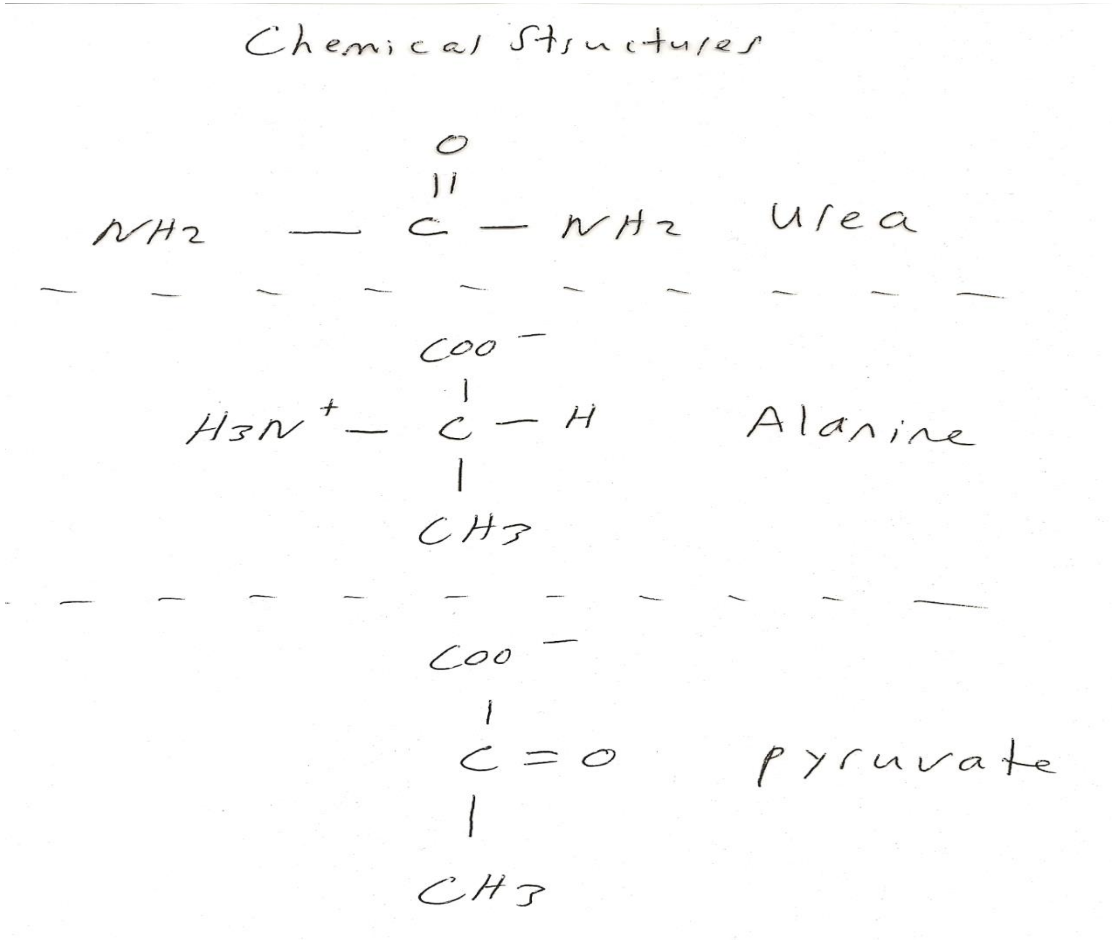
- At same dose glutamine also acts as a GH secretagogue

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Other Amino Acids In Energy Production : thus catabolism of protein during exercise



Urea, Alanine and Pyruvate



GLOBAL
INTEGRATIVE MEDICINE ACADEMY

The Adventures of Glutamine:

- Glutamine is most abundant amino acid in body and blood
- It is the primary fuel for many immune cells, GI epithelial cells (supplementation shown to reduce infection incidence in athletes)
- Glutamine can be formed from alpha-ketoglutarate via the addition of an amide group, donated by aspartate
- In the liver glutamine can help raise glucose levels in catabolic states (and low energy states- AMP and GMP)

- In the kidney glutamine can donate ammonia to buffer states of acidosis (NH_3 to NH_4^+)

- In the brain, glutamate picks up ammonia (NH_3) to become glutamine and transports it to the liver, which deaminates glutamine to discard urea. Ammonia is very toxic to brain cells, thus glutamine transports it in non-toxic form to liver

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

- Ornithine alpha-ketoglutarate can also increase glutamine levels, and like glutamine acts as a GH secretagogue at 10 gm per day. (more potent than glutamine). It consists of ornithine bound to two molecules of alpha-ketoglutarate

- Alanine and glutamine account for 50% of the total alpha-amino nitrogen released by skeletal m during exercise.

- Essentially the amide groups from valine, leucine, isoleucine, aspartate and glutamate are transferred to either pyruvate or glutamate to make alanine and glutamine, which travel to the liver to support glucose synthesis

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Original Protein Studies With Athletes:

- Over 50% of dry wt of body is protein (m. is 22% protein)

- The current RDA for protein does not take into account the catabolism of m. protein induced by exercise, cortisone secreted in response to the stress of exercise, and the age-related decline of hormones. ***The RDA is 0.8 gm/kg***

- Gontez (1974) – 2 hrs/day of exercise produced negative nitrogen balance at 1.5 gm/kg/day protein intake (further substantiation has followed)

- Endurance athletes require 1.14-1.39 gm/kg/day protein to prevent negative nitrogen balance (Tour de France cyclist – 1.8 gm/kg/day)

- To gain lean mass, may require up to 3.5 g/kg/day protein intake, depending upon training employed (Many athletes consume at least 2 gm/kg/day)

- Over consumption raises BUN, keep below 10-14 mg/dL

Protein Quantity/Quality And Growth (animal studies)

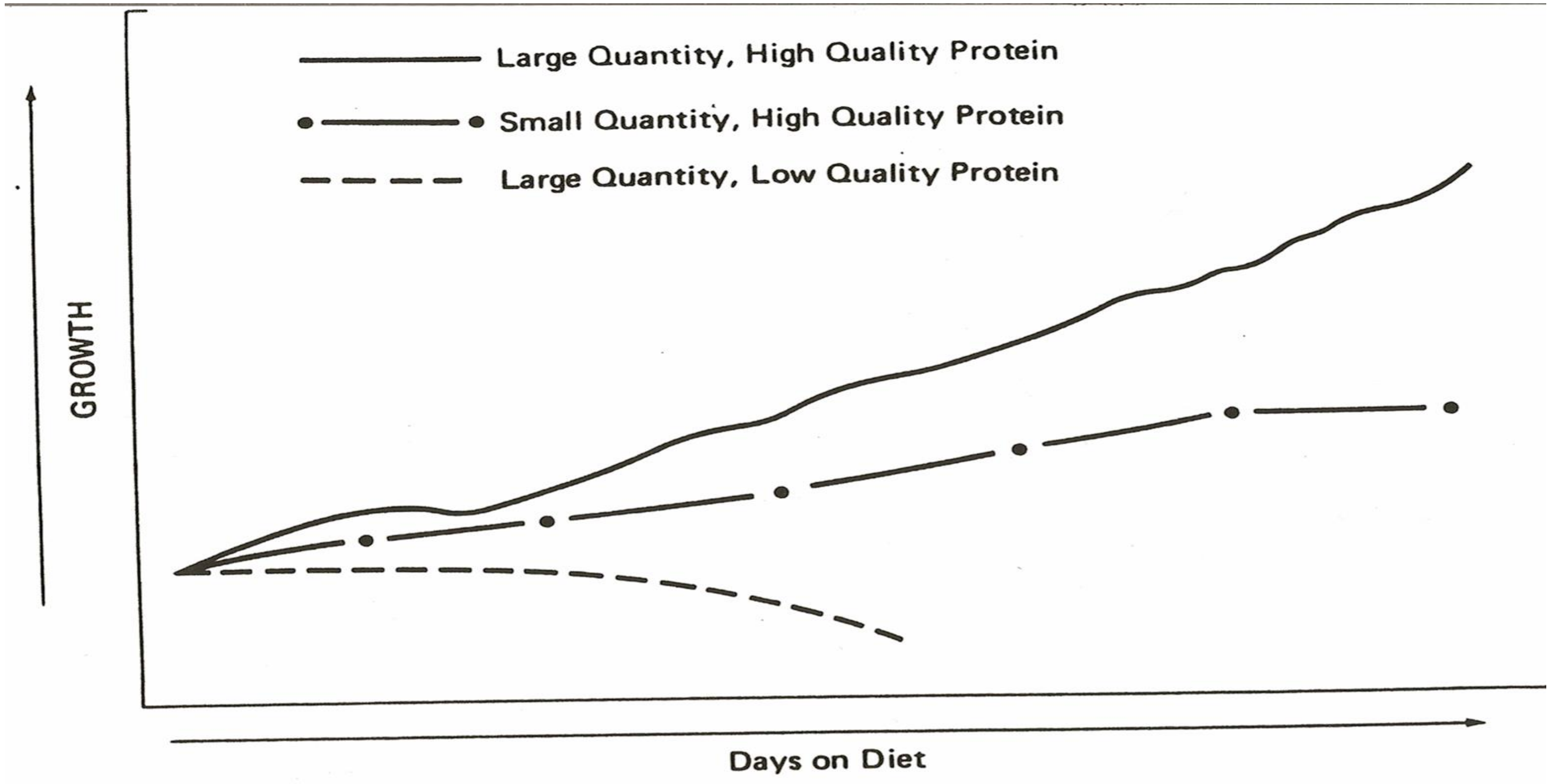


FIGURE 5.2. Effects of three different protein diets on growth of laboratory animals.

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

1.5 gms Protein/Kg Shows Positive Nitrogen Balance

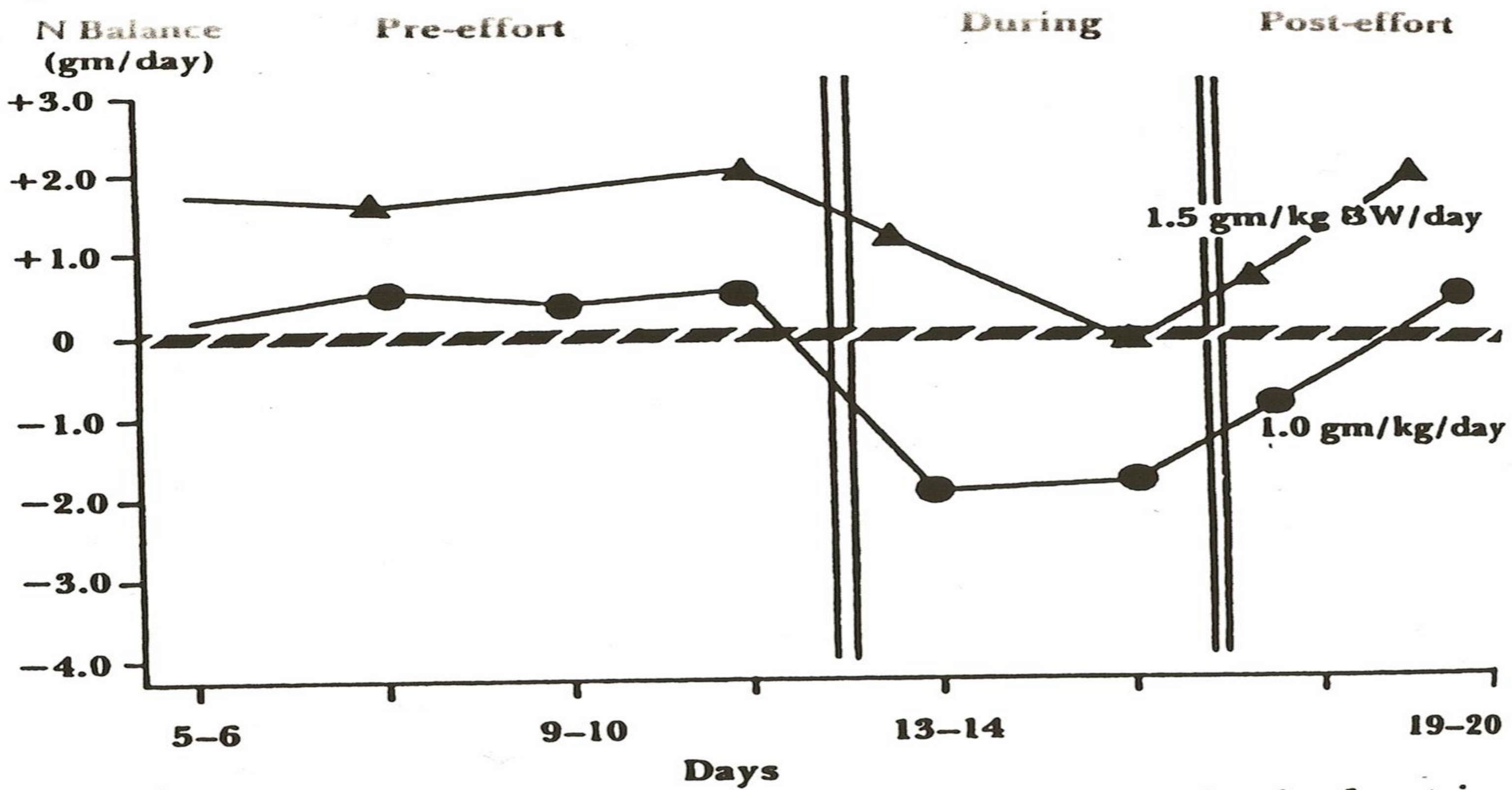


Figure 6: Effects of exercise on nitrogen balance at different levels of protein intake. Redrawn from Gontzea, References 6 and 7.

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Low Fat Protein Sources

- Chicken Breast, Turkey Breast (3 oz) ---------------25 gm
- Most Fish (3 oz) --15-20 gm
- 3 Egg Whites -- 21 gm
- Cottage Cheese (3 tablespoons) ---------------------10 gm
- Non Fat or 1% Milk or Yogurt (8 oz) ----------------9 gm
- Kidney beans (1/2 cup) --------------------------------7.5 gm
- Most beans and peas (1/2 cup) ---------------------- 4–6 gm
- Cooked Pasta (1 cup) --------------------------------- 7 gm
- Cooked Rice (1 cup) ---------------------------------   4 gm
- Soy Milk (1 cup) ---4 gm; Soy Cheese (1 oz) ------7 gm
- Bread (1 slice) -----2–3 gm: Bagel (1) ---------------7 gm
- Most Fruit and Vegetables (1/2 cup) ------------------1-3 gm
- Whey Protein Shake ---------------------------------------25 gm/ 2 scoops

Updated Protein Facts and Consideration (Reference 1)

- Catabolism of protein increases water loss from the body.

- Waste products of protein catabolism leave the body dissolved in fluid in the urine. As such, obligatory water loss is greater with protein catabolism when used as an energy source or when too much protein is consumed and converted to CHO or fat. Get greater water loss and risk of dehydration during exercise if not careful.

- Muscle Protein Synthesis rises post strength training and aerobic training. MPS has been shown to increase 10-80% in the 4 hours following aerobic exercise and MPS remains elevated for the next 24 hours. Thus, protein requirement must factor in protein catabolism during exercise and maximizing MPS post exercise for 24-hour period.

- Greater oxidation of Branched-chain amino acids (BCAA) occurs within exercising muscles itself, than previously thought, aside from alanine leaving muscle to become glucose in the liver. Greater BCAA catabolism than previously thought as BCAA themselves serve as an oxidative fuel for the exercising muscle (intramuscularly). This has re-opened debate about protein requirements, which are now higher than originally reported.

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

- As exercise progresses, the concentration of plasma urea also increases, coupled with a dramatic rise in nitrogen excretion in sweat. This often occurs without any change in urinary nitrogen excretion. (early studies only measured urinary nitrogen excretion and thus underestimated protein catabolism during exercise).

- It turns out that sweat mechanism are an important excretion route for nitrogen (from protein deamination during exercise). Urea production does not reflect all aspects of protein breakdown during exercise because the oxidation of both plasma and intracellular leucine (a BCAA) increase during moderate exercise, independent of changes in urea production.

- Protein use for energy reaches its highest level in a glycogen depleted state. Thus, CHO intake and replenishment spares protein catabolism during exercise to some degree.

- Although an exact protein requirement is still being debated the following is a prudent guideline:
  For Endurance Athletes – 1.2-1.4 gm/kg - protein daily

- For Resistance Training Athletes – 1.8 gm/kg – protein daily

International Society of Sports Nutrition Position Stand: Protein and Exercise
Journal of the International Society of Sports Nutrition (2017)

Key Points:

- Proteins provide the building blocks of all tissues via their constituent amino acids. Athletes consume dietary protein to repair and rebuild skeletal muscle and connective tissue following intense training bouts or athletic events.

- There are 20 amino acids, comprised of 9 Essential Amino Acids (EAAs) and 11 non-essential amino acids (NEAA's). EAA's cannot be produced in the body and therefore must be supplied by the diet.

- Research shows that products containing animal and dairy-based proteins contain the highest percentage of EAA's and result in greater hypertrophy and protein synthesis following resistance training when compared to a vegetarian protein-matched control, which typically lack one or more EAA's.

- EAA's appear to be uniquely responsible for increasing MPS with doses ranging from 6-15 gm all exerting stimulatory effects. In addition, doses of approximately 1-3 gm of leucine per meal appear to be needed to stimulate protein translation machinery.

- Branched-chain Amino Acids (BCAA's - leucine, isoleucine and valine) exhibit individual and collective abilities to stimulate protein translation. Thus, the prioritization of feeding protein with adequate levels of leucine/BCAAs will best promote increases in MPS.

- Originally studies (1980's and 1990's) showed that protein needs were 50-175% greater in athletes than sedentary controls.

- An acute exercise stimulus, particularly resistance exercise, and protein ingestion both stimulate muscle protein synthesis (MPS) and are synergistic when protein consumption occurs before or after resistance exercise.

- For body muscle mass and for maintaining muscle mass through a positive muscle protein balance, and overall daily protein intake in the range of 1.4-2.0 gm protein/kg body wt/day is sufficient for most exercising individuals, a value that falls in line within the Acceptable Macronutrient Distribution Range published by the Institute of Medicine for protein.

- The current RDA for protein is 0.8 gm/kg body wt, which not appropriate for training athletes to meet their daily needs.

- Some evidence suggests that protein intakes above 3.0 gm/kg/d may have positive effects on body composition in resistance-trained individuals who are restricting calories to promote loss of fat mass.

- This extra protein helps increase lean mass gains and increases fat loss to improve overall body composition. (Increased protein intake with some CHO and fat restriction in diet).

- It is suggested that individuals trying attempting to restrict caloric intake should consume three to four whole meals consisting of 20-40 gm of protein per meal, which favorably promotes MPS.

- Although one study showed that a dose of 70 gm protein promoted a more favorable net balance of protein when compared to a 40 gm dose to due to stronger attenuation of rates of muscle protein breakdown.

- However, general agreement on safe and effective approach to decrease body fat, while exercising to increase lean mass (and metabolic rate) is to ingest 20-40 gm of protein at each of three or four meals per day, while restricting CHO and fat intake.

- Regarding protein intake per serving the general agreement is 0.25 gm high quality protein/ kg body weight or an absolute dose of 20-40 gm protein per serving. Older and elderly subjects appear to require protein dose of 40 gm per serving to optimize MPS.

- Spacing intake of protein out throughout the day appears to enhance MPS (and anti-catabolic effects) than one large protein serving. Thus, 3 – 4 protein doses throughout the day, and 30-mins prior to sleep, appears to be best approach to maximize MPS.

- Acute protein doses should strive to contain 700-3000 mg of leucine and/or higher relative leucine content, in addition to a balanced array of essential amino acids

- The protein intake doses are best distributed evenly throughout the day every 3-4 hours.

- Once again, pre or post workout protein ingestion works equally well and thus it comes down to personal preference to some degree.

- Research indicates that rates of MPS rapidly rise to peak levels within 30 mins of protein ingestion and are maintained for up to three hours before rapidly beginning to lower to basal rates of MPS even thought amino acids are still elevated in the blood. In fact MPS rates can be increased three-fold within 45-90 mins post exercise in presence of 48 gm of whey protein ingestion.

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

- **Endurance Training and Protein:** Protein During Exercise: adding protein to fluid, CHO, electrolyte replenishment during intensive bout of endurance exercise may suppress rise in plasma proteins linked to myofibrillar damage and reduce feeling of soreness.

- **Resistance Training:** Quality and quantity of protein intake (with emphasis on leucine protein content) and co-ingestion of additional dietary ingredients that favorably impact strength (i.e. creatine, HMB, growth hormone secretagogues) help to maximize strength and lean mass gains.

- MPS increases approximately 30-100% in response to a protein-containing meal to promote positive net protein balance, and the major contributing factor to this response is the Essential Amino Acid (EAA) content.

- During the post-prandial phase (1-4 hrs after a meal) MPS is elevated, resulting in a positive muscle protein balance. In contrast, MPS rates are lower in the fasted state and muscle protein balance is negative. Protein accretion only occurs in the fed state. The concentration of EAA in the blood (plasma) regulates protein synthesis rates within muscle at rest and post exercise. Protein plus CHO intake after strenuous **endurance** exercise stimulates contractile MPS via similar signaling pathways as resistance training.

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

- Muscles seem to be sensitized to protein feeding for at least 24 hrs after exercise, as protein feeding within this time frame has been shown to produce higher net stimulation of MPS and protein accretion than the same meal consumed after the 24-hour post exercise period.

- Insulin, from CHO and protein ingestion appears to act mostly as anti-catabolic agent, although insulin has been shown to increase MPS in the long-term. A single dose of **45 gm** of whey protein isolate alone can produce sufficient insulin effect to exert anti-catabolic effects.

- CHO also replenishing liver and muscle glycogen, while increasing insulin's effect on MPS and anti-catabolism of muscle protein.

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

- **Pre-sleep Protein Consumption Increases Lean Mass, strength and morning metabolic rate:** 30-40 gm protein (casein) ingested 30-min prior to sleep or via nasogastric tubing increased overnight MPS in both young and old men.

- Likewise, 30 gm of whey protein, 30 gm casein protein and 33 gm CHO consumed 30-min prior to sleep resulted in an elevated morning resting metabolic rate in young fit men compared to a non-caloric placebo.

- Over a 12-week period results showed that the group receiving a protein-centric supplement (27.5 gm casein protein, 15 gm CHO, 0.1 gm of fat) each night before sleep had a greater improvement in muscle mass and strength compared to the group consuming the non-caloric placebo. (consider non-fat, sugar-free Greek Yogurt – 18 gm protein per 8 oz serving; possibly add small amount of high-fiber, low sugar cereal or fruit, as late-night snack 30-mins before bedtime. Greek Yogurt is high in EAA and Leucine content).

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Protein Sources:

1. Milk Protein:

- Milk protein has been researched extensively. Consuming milk following exercise has been demonstrated to accelerate recovery from muscle damaging exercise, increase glycogen replenishment, improve hydration status, and improve protein balance to favor synthesis, ultimately resulting in increased gains in both neuromuscular strength and skeletal muscle hypertrophy. Adding milk or whey protein isolate (0.4 gm/kg) to a moderate but not high carbohydrate-containing beverage promotes increased rates of muscle glycogen replenishment following hard training.

- The protein intake also facilitated repair and recovery of the exercised muscle. Whey protein has been shown to enhance glycogen synthesis in the liver and skeletal muscle more than casein in an insulin-independent fashion by up-regulating glycogen synthase enzyme.

- Milk can be fractionalized into two protein classes: Casein and Whey

- Both of these have high leucine content. Whey is 11% leucine and casein is 9.3% leucine.

2. Whey Protein – is water soluble and mixes easily, and is rapidly digested.

- Whey Protein contains an array of biologically active peptides whose amino acids sequences give them specific signaling effects when liberated in the gut. None only is whey protein high in beta-lactoglobulin and alpha-lactalbumin (75% of total bovine whey protein), but it also rich in EAA's (approximately 50% by weight).

- Whey protein also shown to enhance lymphatic and immune system responses. In addition, alpha-lactalbumin contains an ample supply of tryptophan, which increases cognitive performance under stress, improves the quality of sleep, and may also speed wound healing.

- In addition, lactoferrin is also found in milk and in the whey protein, and has been demonstrated to have anti-bacterial, anti-viral and antioxidant properties. Whey protein may also bind iron and enhance its absorption from the gut.

3. Casein Protein – is water insoluble, coagulates in the gut an digested more slowly than whey protein. Casein also contains opioid peptides, which slow gastric motility.

- In general, studies show that whey protein supplementation, due to its faster-digesting qualities, may be more beneficial for skeletal muscle adaptations than slower digesting casein protein.

- An important study showed greater lean mass gains (5.0 vs 0.8 kg) in body builders using whey protein supplementation for 10-weeks compared to those using casein protein.

GLOBAL INTEGRATIVE MEDICINE ACADEMY

Protein Methods of Processing and Preparations: Protein Concentrates, Filtration, Hydrolyzed Proteins, Digested Protein:

- **Concentrates:** Sports Nutrition Protein Products use concentrations that are 70-80% protein. As extra filtering steps are added, the purity of the final product increases and when a final product yields greater than 90% protein, it is considered a isolate protein (Protein Isolate)

Filtration methods vary:

- **Ion Exchange Method** – exposes whey protein to hydrochloric acid and sodium hydroxide, thereby producing an electric charge on the proteins that can be used to separate lactose and fat. This method is relatively inexpensive and produces the highest protein concentration. It may slightly denature some of the peptides, however,

- **Cross-flow microfiltration and Ultra-microfiltration** - separates protein from fat and lactose using ceramic membranes. The whey protein gets trapped in the membrane while the lactose and other components flow through. The advantage is no denaturing of proteins and is considered, therefore, to be of higher quality. But this process is more expensive increasing the price of finished product, compared to ion exchange method.

- **Hydrolyzed Protein:** Hydrolyzed protein products have already been exposed to some digestive enzymes during processing, which cause hydrolysis of the proteins into oligopeptides 2-8 amino acids in length or are fully hydrolyzed into individual amino acids. Absorption of individual amino acids and various small peptides (di,tri, tetra) into the blood occurs inside the small intestine through separate transport mechanisms.

- Research indicates that amino acids are absorbed more rapidly than complete proteins, which may result in a more favorable anabolic hormonal environment for MPS synthesis and muscle repair. However, more studies are required to confirm these findings and to support the addition of digestive enzymes to protein supplement products.

4. Egg Proteins

- Egg protein studies show that egg protein increase MPS and eggs are a respectable source of leucine. Studies have included 20-40 gm of egg protein, ingested after resistance training, with objective increase in muscle mass and plasma proteins.

5. Beef and other Flesh Proteins

- Beef protein, at a dose of 30 gm, from the consumption of 10.5 gm of beef has been shown to increase MPS in young and elderly subjects. Both beef and chicken also contain creatine, found mostly in muscle tissue (30 mmol/kg or 4-5 gm/kg). Vegetarians have lower total body creatine stores than omnivores, which demonstrates that regular meat eating has a significant effect on human creatine status. Creatine supplementation in vegetarians has been shown to increase their creatine status, however. Meat intake may also help to boost or maintain IGF-1 levels, which have important influences on lean mass and anabolic metabolism.

6. Meat vs Plant-based Proteins:

- Vegetarians can ingest complete proteins by combining various plant foods and adding additional vegetarian-based supplementation, such as soy protein and/or rice protein (and also creatine, maybe HMB etc.). Soy is considered a lower quality complete protein, but it is a complete protein- containing all EAAs. Soy contains lower amounts of BCAA and the proportions of EAA is inferior to that of animal proteins, including dairy and eggs.
- Soy phytoestrogens may also inhibit the mTOR pathway, which is a key intracellular signaling mechanism to up-regulate MPS. Rice protein is quite rich leucine, and one study showed that rice protein provided comparable muscle mass gains as whey protein in participants engaging in weight training for 8 weeks.

7. Protein Blends

- Some studies suggest that Whey plus Casein Protein Blends may provide greater lean mass gains than Whey or Casein protein provided individually. Whey, Casein and Colostrum Blends have also shown impressive results in preliminary studies.

Major Criteria for Protein MPS Efficacy:

- Rate of protein digestion in the gut – faster digesting proteins include whey and eggs, soy and very lean cuts of meat- 95% fat-free (fat slows down gastric emptying). Casein and fatty meats have are digested more slowly.
- Leucine content – leucine up-regulates the mTOR pathway signaling mechanism which up-regulates genes for MPS. Leucine content of important protein sources include:
- Leucine-enriched Wheat Protein – 6.8 %
- Soy – 8.0%
- Egg – 8.8%
- Whey – 11%

- Studies showed that wheat and soy did not stimulate MPS above fasting levels, whereas egg and whey protein significantly increased MPS rates, with MPS for whey protein being greater than egg.

Conclusion – athletes should utilize protein sources that are rapidly digested and have high leucine content to maximize MPS.

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Protein Safety Regarding Kidney and Liver Damage:

- Protein restriction is an important aspect of managing end-stage kidney disease. Some doctors have expressed concern about high protein intakes and protein supplements damaging the liver and kidneys of otherwise health individuals and/or promoting decline in renal function.

- Numerous short term and long-term studies (up to one year using 3.3 and 2.5 gm protein/kg/wt/day) using dosages as high as 4.4 gm protein/kg/d in some short-term studies, have not shown any harmful effects on kidney or liver function or alterations in clinical markers of metabolism and blood lipids.

- As such the ISSN concludes “multiple review articles indicate that no controlled scientific evidence exists indicating that increased intakes of protein pose any health risks in health, exercising individuals. Statements by large regulatory bodies have also indicated that concerns about one’s health secondary to ingesting high amounts of protein are unfounded”.

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Leucine Regulates Translation Initiation of Protein Synthesis in Skeletal Muscles after Exercise: The Journal of Nutrition (2006)
Norton L.E and Layman DK.

- After an overnight period without food there is protein synthesis decreases by 15-30% depending on the length of the fast. Protein catabolism continues until protein ingestion occurs to stimulate protein synthesis. After a meal as nutrients are absorbed, the rate of protein synthesis increases.

- During exercise (endurance and resistance training) there is net catabolic effect on muscle metabolism. Protein turnover remains negative until adequate dietary protein and energy are available for recovery.

- Contrary to what occurs at the end of exhaustive **endurance** exercise, at the end of exhaustive **resistance training** protein synthesis is increased. Yet a single bout of exhaustive resistance training still has a net catabolic effect to increased protein degradation during training routine.

Amino acid metabolism is skeletal muscle is limited to six amino acids:

- Glutamate
- Aspartate
- Asparagines
- Leucine – a BCAA
- Iso-leucine -a BCAA
- Valine – a BCAA

- Among these, leucine has the noteworthy effect on up-regulating protein synthesis.

Leucine and MPS:

- **Leucine increases MPS via several established pathways:**

- Up-regulation of protein synthesis initiation factor 4E (eIF4E) and 4G (eIF4gE) and ribosomal S6 (rpS6)

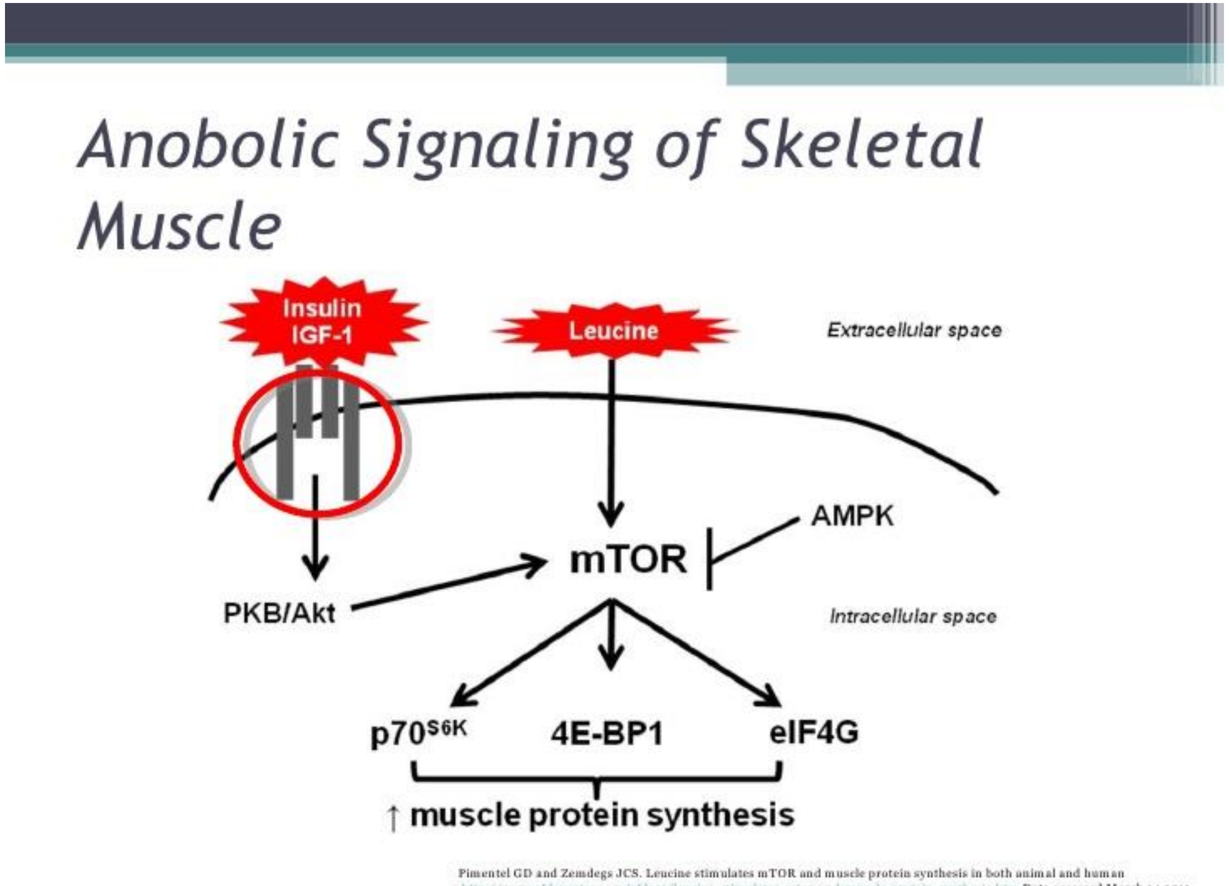
- Up-regulation of insulin release from pancreatic beta cells

- Up-regulation of the mTOR pathway, which also activates 4E and S6

- Exhaustive or prolonged low frequency exercise inhibits the mTOR pathways, including inhibition of 4E and S6. As well, plasma leucine concentrations decrease dramatically at the end of exhaustive endurance exercise.

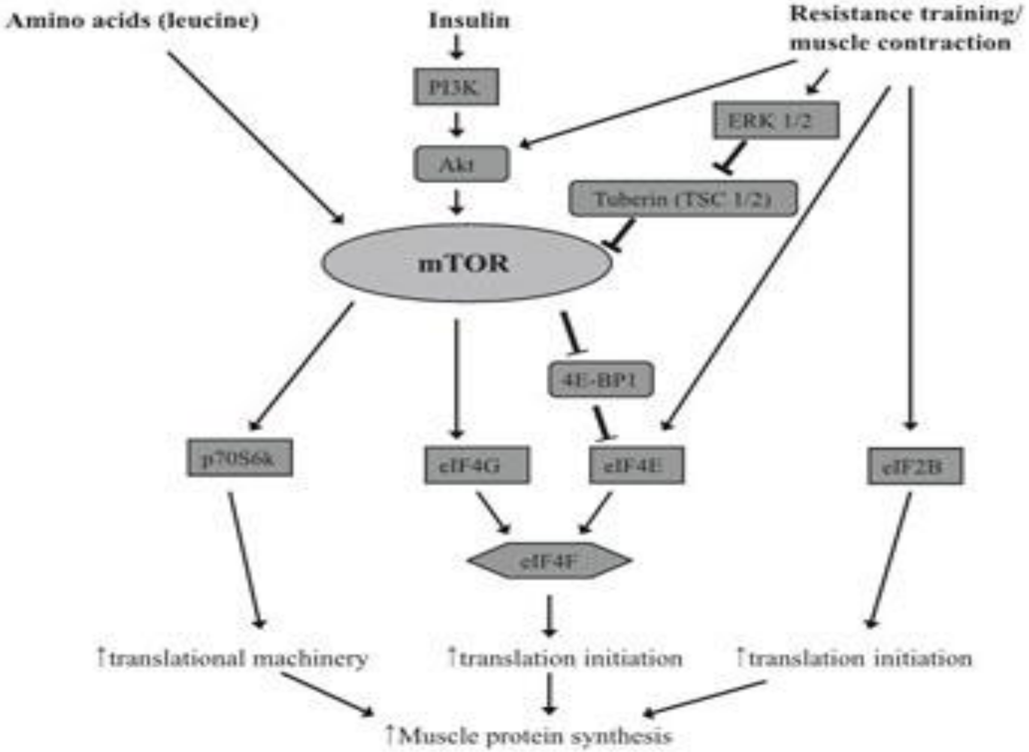
GLOBAL INTEGRATIVE MEDICINE ACADEMY

Leucine increases MPS via up-regulation of mTOR pathway and modulates insulin-phoshoinositol -3 kinase (P13K) pathway, which also increase MPS



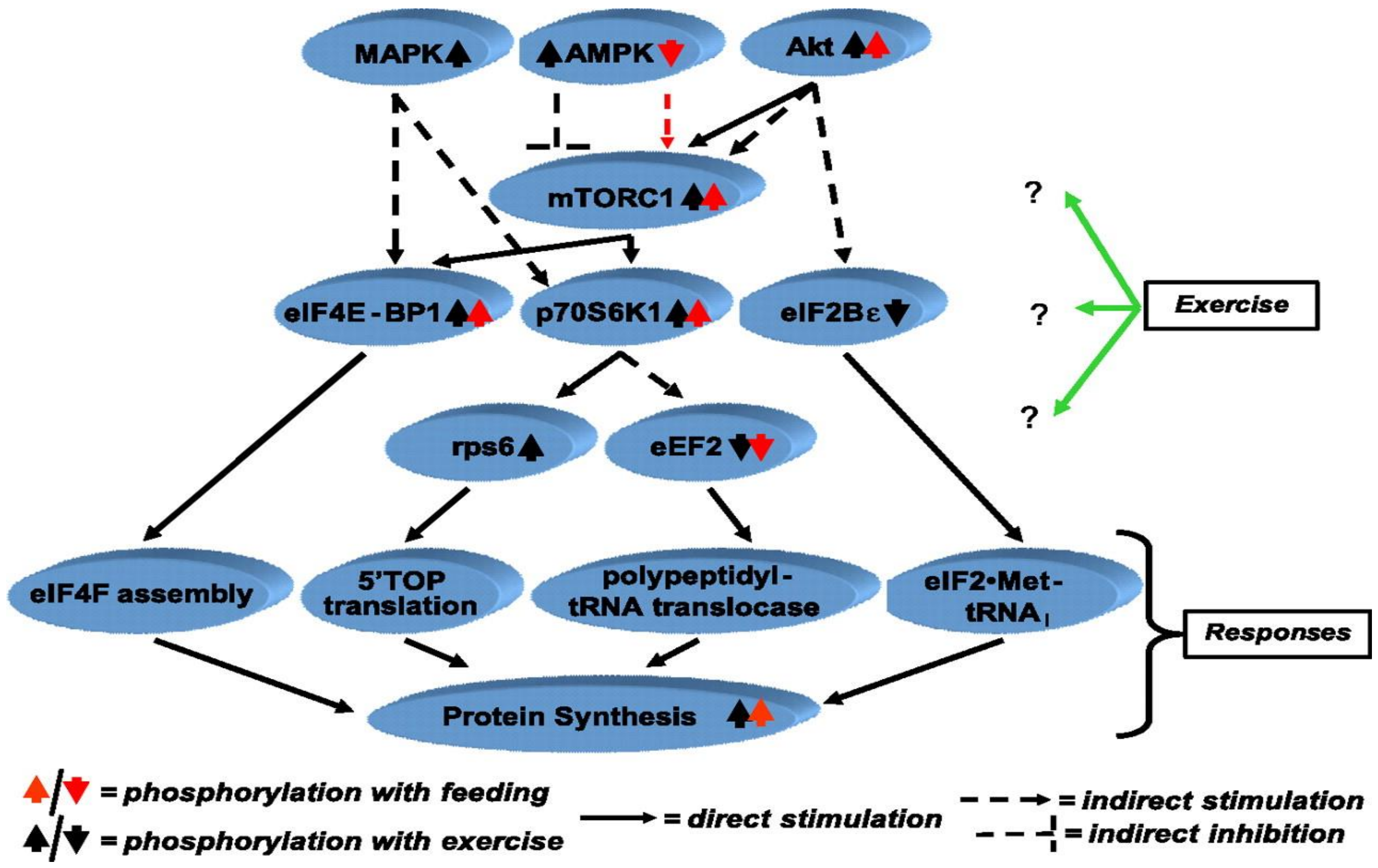
MPS signaling pathways (leucine, insulin, resistance training work synergistically)

Fig. 2. Proposed intracellular signaling pathways in which mammalian target of rapamycin (mTOR) plays a key role integrating the stimulating effects of amino acids, insulin, and muscle contraction on muscle protein synthesis. Arrows indicate activation; solid lines indicate inhibition. See text for complete details. BP1, binding protein 1; eIF, eukaryotic initiation factor; extracellular-related kinase, ERK; PI3K, phosphatidylinositol 3 kinase; TSC, tuberous sclerosis complex.



Leucine also stimulates the eIF4E, which also promotes MPS

- (J Nutr LE Norton et al. 2006)



- Post exercise supplemental leucine increases intracellular leucine concentration, which directly stimulates mTOR and 4G, allowing recovery of muscle protein synthesis.

- The combination of leucine plus CHO appears to produce a synergistic effect on recovery presumably through the combined effects of leucine on mTOR and insulin on PI3-kinase and PKB, resulting in reduced AMPK and TSC2 activity, where AMPK and TSC2 reduce 4E activity and reduces protein synthesis.

- Dietary BCAAs reach the blood virtually unaltered from their level in the diet; thus, leucine reaches peripheral tissues in direct proportion to its dietary intake. During exercise there is increased release of leucine from the visceral tissues (liver and gut) and movement towards skeletal muscle, helping to supply skeletal muscle with more available leucine.

- Constant influx of leucine to skeletal muscle is buffered by the presence of BCAT (branched-chain amino acid transferase) and BCKDH (branched-chain alpha-keto acid dehydrogenase), the first two enzymes catalyzing BCAA degradation (leucine, isoleucine and valine). The higher the BCAA content in skeletal muscle, the more active are BCAT and BCKDH.

- Under normal condition BCKDH is normally less than 20% active, but can increase with higher intracellular concentrations of BCAAs. Thus, after a meal, the skeletal muscle concentrations of BCAA may increase by 2-3fold, but the overall net change in leucine concentration remains much smaller due to increased activity of BCAT and BCKDH. Yet the presence of high levels of leucine arriving in skeletal muscle up-regulates MPS to a significant degree.

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Summary

- Leucine is a strong regulator of protein and amino acid metabolism in skeletal muscle:
- Leucine up-regulates initiation factors 4E, 4G and S6 in protein synthesis
- Leucine stimulates the PI3-kinase signal transduction pathway in protein synthesis.
- Leucine up-regulates the mTOR pathway in protein synthesis
- High levels of intracellular skeletal muscle leucine increase activity of BCAT and BCKDH enzymes, catabolizing BCAA.
- Leucine inhibits the action of pyruvate dehydrogenase, which is a rate limiting step to burn leucine (in the form of pyruvate) in oxidative metabolism (via the citric acid cycle).

- Carbohydrates, nonessential amino acids, and other essential amino acids do not have stimulatory effects on protein synthesis when compared with leucine.

- However, in most cases, the combination of amino acid supplementation with CHO produces additive effects on stimulation of the PI3-kinase and mTOR pathways, producing the maximum rates of protein synthesis during recovery.

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

J Nutr. Norton LE et al. Branched-chain amino acids in exercise. 2006
http://jn.nutrition.org/content/136/2/533S.short

Post exercise supplemental leucine increases intracellular leucine concentrations, which directly stimulates mTOR and eIF4G, allowing recovery of muscle protein synthesis.

The combination of leucine plus CHO appear to produce a synergistic effect on recovery , presumably through the combined effects of leucine on mTOR and insulin on P13-kinase, resulting in reduced AMPK and TSC2 activity. AMPK and TSC2 are increased during endurance exercise, which block muscle protein synthesis.

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

- A review paper in 2015 published in the British Journal of Nutrition showed that leucine supplementation increased muscle protein fractional synthesis rate in elderly individuals, and thus may of benefit to address sarcopenia (the degenerative loss of skeletal muscle mass in this population). Leucine is proven to be a powerful nutritional signaling agent for MPS, as suggested by the nine randomised control trials reviewed in this published paper.

Reference:

- (https://www.cambridge.org/core/journals/british-journal-of-nutrition/article/effectiveness-of-leucine-on-muscle-protein-synthesis-lean-body-mass-and-leg-lean-mass-accretion-in-older-people-a-systematic-review-and-metaanalysis/3EC91F121380499B37781A1E03515900)

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Resistance Training in Older Subjects

- Resistance Training is Proven to Increase Muscle Size (12% in 9 weeks) and Muscle Strength (almost 30% in 9 weeks) in men and women in their 60 and 70's.

- Other studies in patients 65-85 years, also showed improved bone density, decreased blood glucose in type 2 diabetics

- The American Heart Association and the American College of Sports Medicine recommend that all healthy adults do:
  8-10 strength training exercises at least 2x per week that incorporate six of the major muscle groups (chest, shoulders, arms, back, abdomen and legs) P. 154

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

AMPK and TSC2 Block Protein Synthesis During Endurance Exercise and Low-Energy Fasting State

- AMPK and TSC2 are increased during endurance exercise, which block muscle protein synthesis

1. AMPK stands for: 5' AMP-activated protein kinase or **5' adenosine monophosphate-activated protein kinase** and is an enzyme that plays a role in cellular energy homeostasis.

- During resistance and endurance exercise, muscle protein synthesis is inhibited. An increase in AMP-activated protein kinase (AMPK) activity has recently been shown to decrease mammalian target of rapamycin (mTOR) signalling to key regulators of translation initiation. (https://physoc.onlinelibrary.wiley.com/doi/full/10.1113/jphysiol.2006.113175)

- AMPK should not be confused with cyclic AMP-activated protein kinase

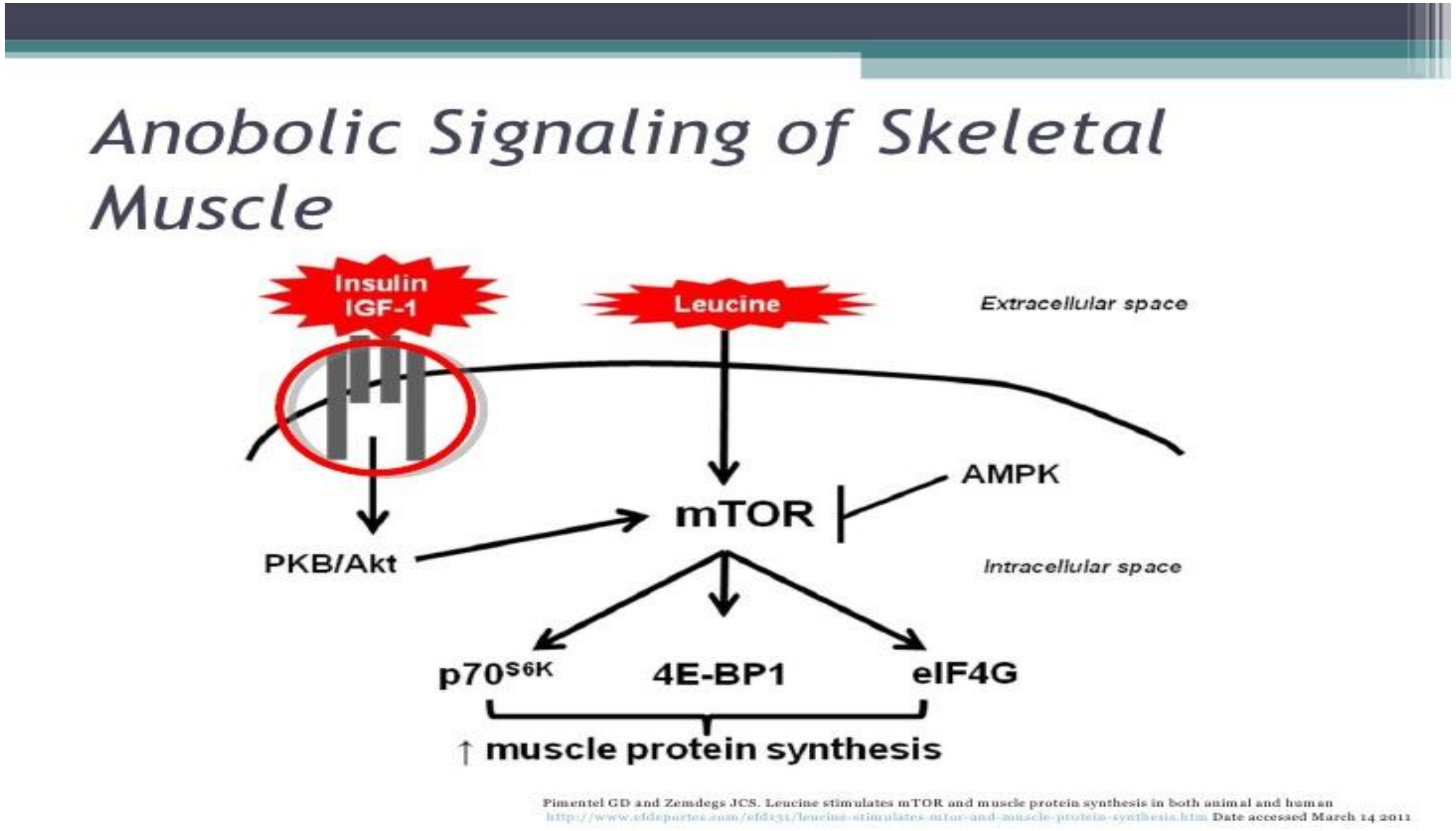
2. TSC2 stand for: Tuberous Sclerosis Complex 2 (**TSC2**), also known as **Tuberin**, and is a protein The TSC1–TSC2 that through its GAP (GTPase-activating protein) activity towards the small G-protein Rheb (Ras homologue enriched in brain), is a critical negative regulator of mTORC1 (mammalian target of rapamycin complex 1).

As mTORC1 activity controls anabolic processes to promote cell growth, TSC2 is exquisitely sensitive to alterations in cell growth conditions.

In a low energy or fasting state, or during exercise, TSC2 inhibits protein synthesis via inhibition of the mTOR pathway.

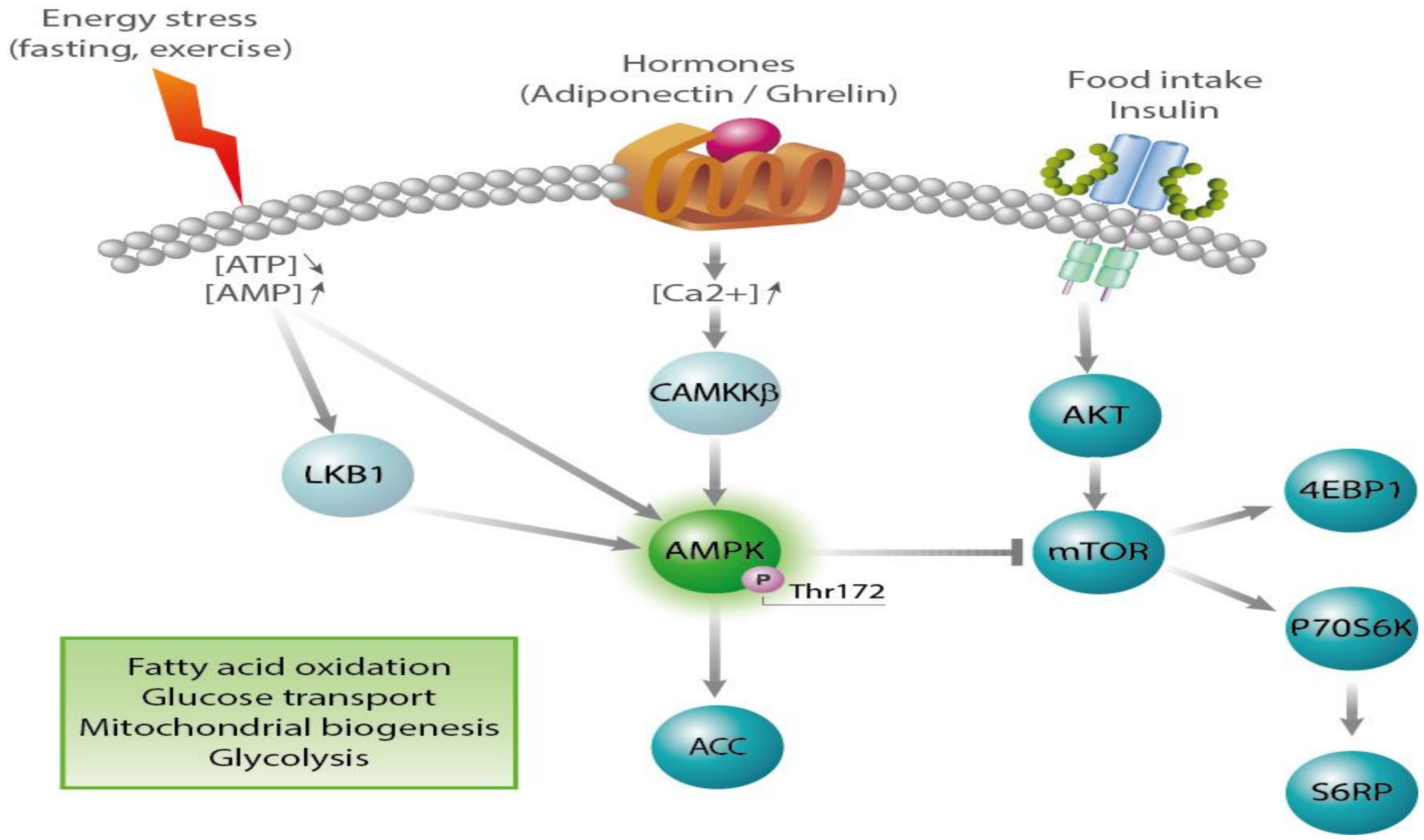
GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Insulin and IGF-1 activate Protein Synthesis via PKB-Akt-mTor pathway. Thus CHO intake and increased release of Growth Hormone (and subsequent IGF-1) increase protein synthesis via this pathway



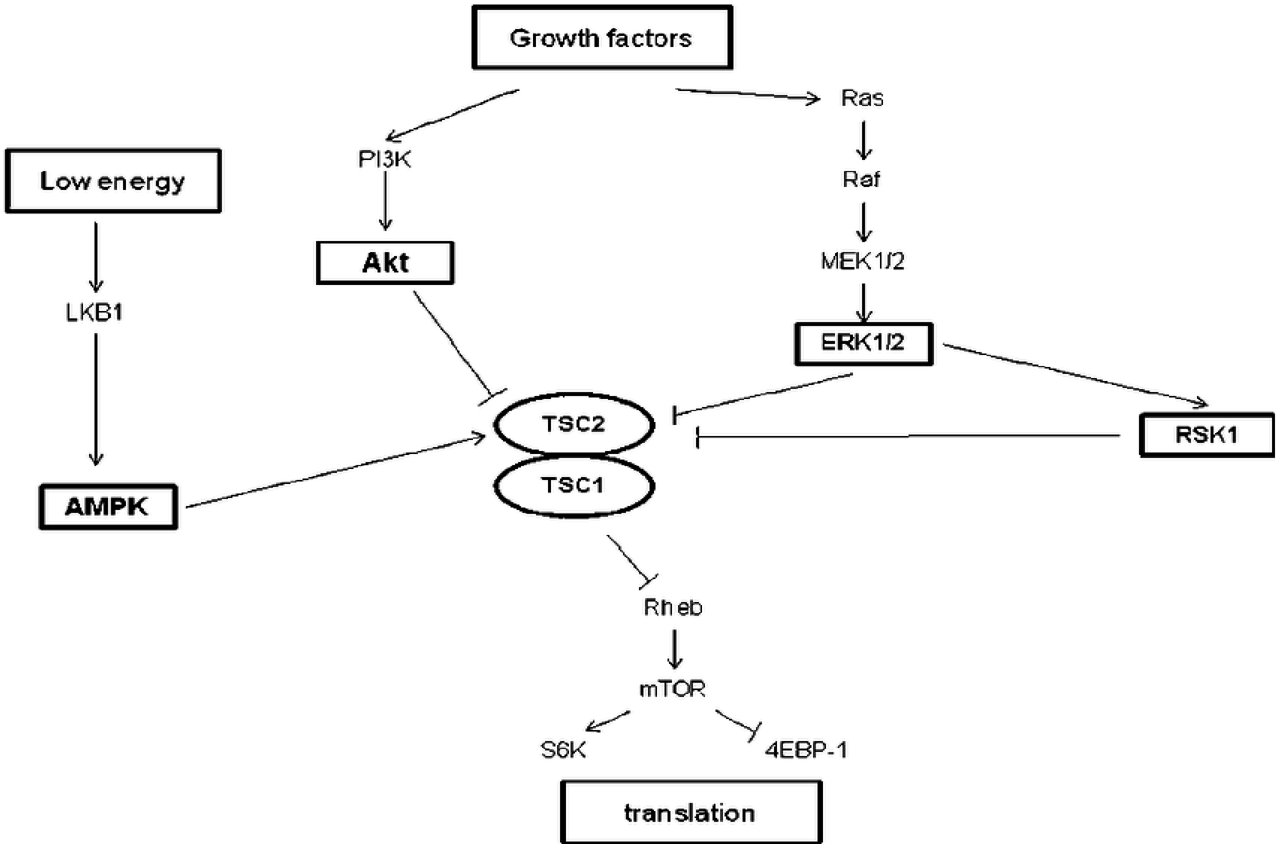
GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Low Energy State, Fasting, Endurance and Resistance Exercise Inhibit Protein Synthesis via Activation of AMPK Pathway – inhibiting mTOR



GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Low Energy State, Fasting and Exercise also Inhibit mTOR via Activation of TSC2



Fat Metabolism: Updated Considerations (Reference 1)

- Each pound of stored fat contains 3500 calories

- FFA coming from fat cells bound to albumin and enter exercising muscle – and enter mitochondria for energy metabolism by action of carnitine-acyl Co transferase (L-carnitine).

- But medium and short-chain fatty acids don't require carnitine-acyl Co transferase (L-carnitine) to enter mitochondria as they can diffuse through mitochondrial membrane on their own to initiate beta-oxidation and energy transfer to ATP via aerobic metabolism. (this is a consideration in patients who have L-carnitine synthesis defects).

- Blood levels of glycerol can largely reflect breakdown of triglycerides from adipose tissue. Glycerol is slowly converted to glucose in the liver during exercise and thus is not a main gluconeogenic precursor for exercise performance and blood glucose maintenance during exercise. Lactate, alanine and glutamine are converted more rapidly by the liver to glucose than glycerol during exercise.

- Considerable fatty oxidation occurs during low-intensity exercise. Fat combustion almost totally powers exercise at 25% of aerobic capacity. CHO and fat contribute almost equally to ATP synthesis at more moderate intensity. As time passes fat contributes more and more at this intensity and can account for nearly 80% of ATP synthesis towards the end of prolonged exercise as glycogen depletion ensues.

3 Sources of Fat for Muscle ATP Synthesis:

1. Lipolysis of adipose triglycerides – albumin-FFA to muscle
2. VLDL and chylomicrons n blood stream as circulating triglycerides
3. Intramuscular lipid stores

- Initially right after exercise begins see drop in blood triglycerides and FFA, then followed by increase FFA from fat cells- triggered by sympathetic NS activation of beta-adrenergic receptors on fat cells with ultimate stimulation of hormone sensitive lipase that products hydrolysis of triglyceride.

- Also drop in insulin triggers hormone sensitive lipase and FFA release. As such, consuming CHO too early during exercise may suppress release of FFA from fat cells, due to effect of insulin.

- In first hour of exercise fat supplies 50% of energy and by the third hour supplies up to 70% of energy.

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Athletes Body Fat:

- Women – 14-20% (24%) body fat. Below 14% get menstrual dysfunction with decreased estrogen production and increased risk of stress fractures and osteoporosis

- Men – 9-12% body fat, although in some sports a lower percentage is seen. Too very low body fat can lead to blindness occurs (dangerous below 3-4%)

Proponents of High-Fat Diet to Enhance Exercise Performance Proven Wrong by Studies:

- Proponents of high fat diet during training argue that it creates adaptations whereby the body starts to burn more fat during exercise, thus sparing glycogen depletion. Indeed high-fat diet has been shown to stimulate adaptive responses that augment fat oxidation.

- But studies demonstrate that high-CHO diet during training is far superior for performance outcomes

- Studies show that the group consuming high-CHO diet performed significantly better after 7-wks of training (102.4 mins) than the group consuming high-fat diet (65.2 mins). When high-fat diet group switched to high-CHO diet during week 8, only a small improvement occurred reaching 11.5 mins occurred.

- Consequently, total overall endurance improvement over the 8-week period reached 115% for the high-fat diet group, whereas the high-CHO diet group realized improvement of 194%. The high-fat diet produces sub-optimal adaptations in endurance performance, which were not fully remedied by switching to high-CHO diet for one week.

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Saturated Fat and Cholesterol In Foods: although containing protein these high fat foods slow protein digestion, which slows MPS. Saturated Fats also raise cholesterol levels, increase blood viscosity and increase CVD Risk, and often increase body fat (dead weight that impairs performance)

Food	Amount	Saturated Fat (gms)	Cholesterol Level (mgs)
Red Meats			
beef	3 oz.	11.1	78
lean beef	3 oz.	3.7	73
beef hotdog	3 oz.	9.9	75
veal (untrimmed)	3 oz.	7.8	84
veal (lean & untrimmed)	3 oz.	3.9	84
lamb (untrimmed)	3 oz.	11.4	81
Pork			
sausage	3 oz.	13.5	75
bacon (cooked slices)	3	3.9	9
Milk			
skim milk (1 cup)	8 oz.	0.1	4
1% milk (1 cup)	8 oz.	1.4	7
2% milk (1 cup)	8 oz.	2.9	14
whole milk (1 cup)	8 oz.	5.3	32
Cheese			
1% cottage cheese	2 oz.	0.3	2
10% cheese	2 oz.	2.8	18
20% cheese	2 oz.	5.8	36
30% cheese	2 oz.	9.4	54
> 30% cheddar cheese	2 oz.	11.2	58
Oils			
palm oil	1 tspn.	2.4	---
cocoa butter oil	1 tspn.	3.0	---
coconut oil	1 tspn.	4.3	---
Other			
cream	1 oz.	6.6	40
whipped cream	1 oz.	4.1	24
ice cream	1 cup	8.9	59
butter	1 tspn.	2.5	12
eggs (whole)	1	1.5	225
egg yolk	100 gms.	10.1	1,480
mayonnaise	1 tspn.	0.6	4
chocolate bar	3 oz.	16.3	18

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Lower Fat and Some High Cholesterol Foods

Food	Amount	Saturated Fat (gms)	Cholesterol Level (mgs)
Chicken			
light meat/no skin	3 oz.	1.0	66
dark meat/no skin	3 oz.	2.1	75
Turkey			
light meat/no skin	3 oz.	1.0	66
dark meat/no skin	3 oz.	1.2	84
Fish			
bass, cod, halibut, sole, red snapper, pike, perch	3 oz.	1.0	54
trout, salmon, tuna, sardines, mackerel, herring	3 oz.	1.0	54
Shell Fish			
crab and lobster	3 oz.	trace	78
shrimp	3 oz.	0.2	128
Organ Meats			
beef liver	3 oz.	1.2	366
chicken liver	3 oz.	1.5	624
brains	3 oz.	1.8	1,680
kidney	3 oz.	3.9	625

Fat Intake:

- Most athletes recognize that keeping their fat intake between 10-20% is desirable to control body fat
- Saturated fat is preferentially stored in fat cells as triglycerides, adding to the dead weight of fat mass, and increasing body fat.
- We will see that esterification of plasma lipids with DHA (omega-3 fat) increases oxygen uptake into muscle cells improving athletic performance

Metabolic Rate, METs and Related Factors: Reference 1

Basal Metabolic Rate:

Men: Ages 20-40: average value equals 38 kcal/m^2/hr (m= square meter of body surface)

Women: 35 kcal/m^2/hr

- Body Surface Area (m^2) = 0.2047 x stature $^{(0.725)}$ x Body Mass
- Where Stature= height in meters (multiply inches by 0.254 to convert to meters)
- Body Mass is weight in kg (divide pounds by 2.205 to convert to kg)

Sample BSA computation – Male 70 inches tall

- BSA = 0.20247 x 1.778 $^{(0.725)}$ x 75 $^{(0.425)}$ =
- 0.20247 x 1.51775 x 6.2647 = 1.925 m^2

- Example: 20-year old who is 70 inches tall:
- BMR = 36.5 kcal/$m^{2/}$hr

- If his BSA was 1.925 m^2 the hourly energy expenditure would be 70.3 kcal (36.5 x 1.925m^2). On a 24-hour basis, this amounts to an (resting daily energy expenditure) RDEE of 1686 kcal (70.3 x 24)

- Most people can sustain metabolic rates that average **10-times the resting value** during big muscle fast walking and hiking exercise and running, cycling and swimming.

- Physical activity generally accounts for between 15-30% of TDEE (total daily energy expenditure)

- **Diet-Induced Thermogenesis** – typically reaches maximum within 1 hour after eating and magnitude can vary between 10-35% of ingested food calories. A meal of pure protein elicits a thermic effect equaling 25% of the meal's total energy content.

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

- **Climate and Thermogenesis** – tropical climates induce an increased BRM effect averaging 5-20% greater than people living in more temperate regions. Exercise performed in hot weather also imposes a small additional metabolic load: about a 5% elevation in oxygen uptake compared to thermoneutral conditions. This is due to direct thermogenic effect of elevated core temperature plus additional energy required to sweat gland activity and altered metabolism.

- During sustained exercise, aerobically fit men and women metabolic rate often increases 20-25 times above resting level to 20 kcal/min – 1200 cals per hour.

- **METs – Metabolic Equivalent** – One MET represents an adult's average seated resting oxygen consumption or energy expenditure – about 250 mL O_2/ min; 3.5 mL O_2/kg/min; 1 kcal/kg/hr

- Thus, a 2 MET activity requires twice the energy of 1 MET – 500 ml O_2 per minute.

- Conversion of MET to kcal/min requires body weight and use of the following conversion:
  1.0 kcal/kg/hr = 1 MET.

- For example, if a person weighing 70 kg bicycles at 10 mph (listed as a 10 MET activity) the corresponding kcal expenditure calculates as follows:
  10.0 METs = 10.0 kcal/kg/hr x 70kg divided by 60 mins
- = 700 kcal divided by 60 mins
- = 11.7 kcal/min

Reference 1. (204-205)

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Energy Expenditure of Some Athletes:

- Elite Marathon Runners and Professional Cyclists – energy output can be 1,000 kcal/hour or higher
- Elite cross-country skiers in training – 3740-4860 kcal per day
- Elite lightweight female rowers in training – 3957 kcal per day
- Tour de France cyclists during event – 6500 kcal/day during nearly 3 consecutive weeks of competition (down to 3,000 kcal/day on rest day and up to 9,000 kcal per day over mountain passes) – by combining liquid nutrition with normal meals, these cyclists nearly matched daily energy expenditure with energy intake.

Adolescent gymnasts often consume (23% of them) less than 1500 kcal per day and more than 405 consumed less than the RDA for:

- Vitamin E
- Folate
- Iron
- Magnesium
- Calcium
- Zinc

High-risk athletes, who participate in arduous training but are often under-nourished include:

- Gymnasts
- Ballet dancers
- Ice skaters
- Weight-class athletes in boxing, wrestling and judo

- These athletes would benefit from upgraded diet and nutritional supplements. (should consider 1.2-1.6 gm protein/kg body wt and avoid training and competing in CHO-depleted state)

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Dietary Composition for Various Athletes

1. Body Builders – High protein diet-40%; 40%-CHO; 20%-Fat (minimal aerobic activity as fear lean mass catabolism)

2. Interval Athletes (hockey, soccer, basketball etc.) – Protein 20-25%; CHO-55-60%; Fat-15-20%

3. Endurance Athletes – Protein-15-20%; CHO-60-70%; Fat -5-20%

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

MET to Calorie Expenditure Conversion

Conversion of MET to kcal/min requires body weight and use of the following conversion:
1.0 kcal/kg/hr = 1 MET.

- For example, if a person weighing 70 kg bicycles at 10 mph (listed as a 10 MET activity) the corresponding kcal expenditure calculates as follows:
  10.0 METs = 10.0 kcal/kg/hr x 70kg divided by 60 mins
- = 700 kcal divided by 60 mins
- = 11.7 kcal/min

Reference 1. (204-205)

Nutritional Strategies

- Day-to-Day
- Pre-Competition/Training
- Immediately Prior to Competition/Training
- During Competition/Training
- First 2 hours Post Competition/Training
- Tournament Day or Weekend Competition Nutritional Strategies

Macronutrients and Performance – Primarily for Endurance Athletes: (Reference 1)

- **Energy Phase** - Consuming a CHO/Protein supplement **before exercise (but not within an hour before) and during exercise extends muscular endurance**: the ingested protein promotes protein metabolism, thus reducing demand for muscle's amino acids (decreased muscle catabolism).

- CHO during exercise suppresses cortisol release, which blunts immuno-suppressive effects of exercise and reduces BCAA catabolism for energy, helping to preserve lean mass.

This supplement should meet the following criteria:

- 20-26 gm of high-glycemic CHO (glucose, fructose maltodextrins)
- 5-6 gm whey protein
- 1 gm leucine
- 30-120 mg Vitamin C
- 20-60 IU Vitamin E
- 100-250 mg sodium
- 60-100 mg potassium
- 60-220 mg magnesium

Anabolic Phase: 45- mins post exercise:

High glycemic CHO plus protein. Criteria includes:

- 40-50 gm high-glycemic CHO (glucose, fructose, maltodextrin)
- 13-15 gm whey protein
- 1-2 gm leucine
- 1-2 gm glutamine
- 60-120 mg Vitamin C
- 80-400 IU Vitamin E

The Growth Phase – from end of Anabolic Phase to beginning of next Work Out

- In the first several hours following work out the criteria includes factors capitalize on sustained insulin sensitivity and thus protein synthesis and glycogen replenishment.
- 14 gm whey protein
- 2 gm casein protein
- 3 gm leucine
- 1 gm glutamine
- 2-4 gm high-glycemic CHO

Then for the next 16-18 hours (**Sustained Segment**) the criteria includes:

- **Protein** - Between 0.91-1.2 gm protein per kg body weight – continue to support lean mass gains (MPS)
- **CHO** - Adequate CHO intake to fully to fully replenish liver and muscle glycogen stores

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Pre-competition Meal (Reference 1)

Key: Adequate CHO and Optimal Hydration

- If competition is in early afternoon, then breakfast becomes critical meal for glycogen replenishment and hydration
- For late afternoon competition then lunch becomes critical meal for glycogen replenishment and hydration
- As a general rule eliminate foods high in lipid and protein content on the day of competition as these foods digest slowly and remain in digestive tract longer than CHO foods of similar energy content. Remember that stress and anxiety on competition day decreases blood flow to gut for digestion and absorption of nutrients (including macronutrients, so a pre-competition meal takes 1-4 hours to digest and replenish muscle and liver glycogen.

Five Reasons to Modify or Abolish High-Protein Pre-competition Meal:

- CHO ingestion replenishes liver and muscle glycogen that occurs during sleep – an essentially fasting state
- CHO digest and absorb more easily and provide energy faster and reduce feeling of fullness following a meal
- High protein meal increases metabolic rate and thermogenesis making it more difficult to prevent rise in core temperature upon exercise participation – decreasing heat dissipating ability of body, which can impair exercise in hot weather.
- Protein breakdown for energy increases water loss to a greater degree than CHO, which can hasten dehydration and decrease ability to maintain optimal hydration and heat dissipation during exercise.
- CHO can be burned anaerobically for all-out sprint activity during competition, which provides competitive advantage if more glycogen replenishment has occurred during pre-competition meal.

Three Requirements of Pre-competition Meal:

- Contain 150-300 gm CHO (3-5 gm/kg body wt) in either liquid or solid form
- Be consumed 3-4 hours before exercising
- Contain relatively little fat and fiber to facilitate gastric emptying and minimize GI distress.

- **Liquid Meals:**
  Although high in CHO, contain sufficient fat and protein to contribute to satiety.

- Effective solutions during day-long swimming and track meets or during tennis, soccer, softball and basketball tournaments

- Athletes can also use liquid meals to help maintain body weight and as a ready source of calories to gain weight if necessary.

- Some Nutritional Bars can provide similar benefits to Liquid Meals, but should not be High Protein Bars, but rather Energy Bars with small amount of protein and fat. These bars require increase fluid intake as they do not provide the fluid content of Liquid Meals.

30-60 Minutes Pre-competition:

- No CHO, other than Fructose within 60 mins of exercise or competition.

During Competition Replenishment:

- CHO replenishment during exercise, beginning at time 60 mins has shown improved endurance performance, but more recently studies show that adding protein to CHO intake (along with fluids and electrolytes) is even more beneficial.

- The addition of protein to the CHO-containing beverage may extend time to fatigue and reduce muscle damage compared to standard CHO beverage only. Best results seem to be with mixture of CHO sources, along with protein.

- The most effective supplement (with 88 randomized studies reviewed) consisted of 3-10% CHO-plus -protein drink that provided 0.7 gm/kg body wt/hr of glucose polymers, 0.2 gm/kg body wt/hr of fructose, and 0.2 gm/kg body wt/hr of protein. (p. 261-262).

- High glycemic CHO intake during exercise does not produce an insulin secretion response due to sympathetic nervous system activation which inhibits release of insulin from pancreas. Also, exercise facilitates glucose uptake by exercising muscle (increasing insulin sensitivity).

- Consuming about 60 gm of liquid or solid CHO each hour benefits intense, long duration (equal to or greater than one hour) aerobic exercise and repetitive short bouts of near-maximal effort.

- The upper limit to oxidize exogenous CHO (CHO consumed during exercise) during exercise is 1.5-1.7 gm (6.0-6.8 kcal) per minute. The maximum absorption rate of CHO from the gut appears to be the greatest rate-limiting step for exogenous CHO oxidation during exercise.

- CHO consumption during aerobic exercise at 60-80% of aerobic capacity postpones fatigue by 15-30 minutes with improved performance in range of 15-35%. Endurance benefits from CHO intake during exercise become apparent at about 75% of aerobic capacity. (p.263)

- To optimize water and CHO absorption, consume a 6% CHO-electrolyte solution that combines fructose, sucrose, each transported by separate non-competitive pathways (p.267)

- New research suggests that adding BCAA to CHO-water-electrolyte solution, consumed during exercise, may further enhance performance by:

1 Increasing insulin secretion to preserve glycogen stores. However, increased insulin release decreases lipolysis in fat cells.

2. Prevent plasma decline in BCAA, which normally allows more tryptophan to bind to transporter to enter the brain and become serotonin, which can produce feeling of fatigue during exercise. BCAA intake competes with tryptophan for transporter into brain, thereby lowering brain levels of serotonin and helping prevent exercise-induced feelings of fatigue (p. 269).

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

- Recall that sustained exercise at or below 50% of maximum intensity relies primarily on energy from fat oxidation, with relatively little demand on CHO breakdown.

- This level of intensity does not tax glycogen reserves to a significant degree and thus, CHO-containing beverages are usually not required by individuals exercising at this intensity unless the exercise is very prolonged.

- At Intensity above 50% of max intensity, exogenous CHO intake during exercise has three major benefits:

1. Spares muscle glycogen, especially in type 1 aerobic fibers.

2. Maintains more optimal blood sugar, which elevates serum insulin to some degree, thus suppressing release of cortisol and GH – thereby preventing headaches, light-headedness, nausea, and other S and S of CNS distress.

3. Supplies muscles with glucose when muscle glycogen levels are depleted in later stages of competition.

Overview to Date and Some Examples

Pre-Training/Competition Meal (3-4 hours prior):

1. For Endurance Athletes and Interval Training-type Sports– up to 60-70% of caloric content is CHO (pasta, rice, potatoes, bread, non-fibrous vegetables, fruit); 20% protein (1.5 oz chicken, or 1/3 to ½ chicken breast, 2 oz fish, 4-6 oz tofu etc. **Plus** – ½ to a 1.0 liter of water of sugar-free, alcohol-free, caffeine-free fluids) – to boost hydration.

Meal Examples:

Pasta in tomato sauce, with a few vegetables and small amount of grilled chicken, shrimp, or fish

Vegetable stir-fry (non-fibrous vegetables) with steamed rice and tofu

Morning: Pancakes with syrup (no butter), and fruit mixed into 4 oz of non-fat, sugar-free Greek Yogurt

Morning: Non-high fiber, Breakfast cereal with skim milk, or Non-high fiber breakfast cereal mixed into 8 oz non-fat, sugar-free plain yogurt.

2. For Body Builder – up to 40% of meal is protein and 40% is CHO, with minimal fat (but can increase fat and decrease CHO provided daily protein reaches 3 gm/kg/d and restrict overall calories from CHO.

Meal Examples:

1-2 Grilled Chicken Breast (25 gm protein per breast) with salad (olive oil and vinegar)

10-12 oz Fish (Grilled or Baked) – with small bean salad or soup

Protein Shake (20-50 gm protein) – blend in water, with ice cubes and small amount of fruit

3. Training Days Combining Weight Training with Endurance Training at Same Work Out (and possibly interval training): Up to 60 % of caloric content is CHO (pasta, rice, potatoes, bread, non-fibrous vegetables, fruit); 20-30% protein (3 oz chicken, or a full chicken breast, 6.0 oz fish, 10-12 oz tofu etc. **Plus** – ½ to a 1.0 liter of water of sugar-free, alcohol-free, caffeine-free fluids) – to boost hydration.

Meal Examples:

Pasta in tomato sauce, with a few vegetables and a whole grilled chicken, or fish (6-8 oz)

Chicken Skewer (or two) with rice and vegetables (or chicken skewer wrap with vegetables and rice)

Chicken, Tofu or Shrimp stir-fry (non-fibrous vegetables) with steamed rice

Protein Shake (30-50 gm) – mixed cold water with ice cubes, fruit and small amount of juice (may add creatine – to be discussed later)

Morning: 12 oz of non-fat, sugar-free Greek Yogurt with fruit mixed in and toast with jam

Morning: Egg white omelet with vegetables, toast and potatoes

30 Minutes Prior to Competition or Training

A. 30 Minutes Prior to Endurance Training/Competition, or Interval-training Sport Training/Competition:

- Mandatory: 13-20 oz cool water (pre-hydration)
- Option = add 20 gm of fructose to 20 oz of water

B. 30 Minutes before Training Days for Interval Athletes and Other Athletes who Perform Both Resistance Training and Cardio Training Together (with or without intervals): This also applies to Body Builder Training:

- Mandatory: 13-20 oz cool water (pre-hydration)
- Option = add branched-chain amino acid mixture to water

Post Exercise CHO Replenishment

- First 2 hours is critical window to restore liver and muscle glycogen – increased glycogen synthase sensitivity

- The use of more simple CHO, or higher GI index foods is preferred over lower glycemic starches and complex CHO foods and the addition of liquid protein to the CHO supplement may even enhance the magnitude of glycogen synthesis.

- During the first 2 hours post exercise – consuming a glucose polymer solution with low osmolality restores glycogen more rapidly than an energy-equivalent solution of monomers with high osmolality. The low osmolality allows faster GI absorption of CHO.

Optimal Glycogen Replenishment Strategy

- Within 15 mins of stopping exercise, consume 50-75 gm (2-3 oz, or 1.0-1.5 gm/kg/body wt) of high-to-moderate glycemic CHO.

- Continue eating 50-75 gm of CHO every 2 hours until achieving 500-700 gm (7-10 gm/kg/body mass) or until eating a large high-CHO meal.

- If immediately ingesting CHO following exercise proves impractical, an alternative strategy involves eating meals that contain 2.5 gm of high-glycemic CHO per kg/body mass at 2,4,6,8 and 22 hours after exercise. This regimen replenishes glycogen to levels similar to those achieved with same protocol begun immediately after exercise.

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

- Note that nibbling on CHO over a 24-hour period, or consuming a high-CHO meal within 2 hours after exercise, followed by some additional CHO intake over the ensuing 22 hours, produce the same net effect on glycogen replenishment (p. 268).

- With correct strategy glycogen replenishment takes place at 5-7% an hour over 24-hour post exercise period. Even under ideal circumstances it takes at least 20 hours to restore depleted glycogen state post exhaustive exercise.

Optimal Glycogen Repletion Benefits 3 Types of Activities

- Regular Intense Training
- Tournament Days
- Competitive events scheduled with only 1-2 days for recuperation

Foods to Avoid During Glycogen Replenishment:

- Pure Fructose
- Milk Products
- Legumes

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

Protein Also Aids in Recovery:

- Consuming an amino acid-protein mixture of whey protein hydrosylate with free leucine and phenylalanine in a CHO-containing beverage facilitates faster glycogen replenishment.

- The amino acids increase insulin release with greater glucose uptake from muscles and thus faster glycogen synthesis. The amino acids may also aid in muscle protein synthesis and muscle repair post exercise.

Fluids: Glucose, Water and Electrolyte Replenishment Considerations: (Discussed in Detail in Sports Nutrition Part 2)

Important to:

- Prevent Dehydration, performance decrements and hyperthermia
- Prevent Glycogen Depletion and provide exogenous source of glucose to muscles for oxidation
- Prevent Hyponatremia

Gastric Emptying Factors:

- **Volume** – increased volume of fluid increases emptying rate
- **Caloric Content** – the greater the calories, the slower the emptying rate (which can impair hydration if CHO concentration above 8%)
- **Osmolality** – increased solute concentration decreases emptying
- **Exercise Intensity** – exercise intensity rate above 75% of maximum decreases emptying rate.
- **pH** – marked deviation from 7.0 decreases emptying rate
- **Hydration Level** – dehydration decreases gastric emptying and increases risk of GI distress.

Sports Nutrition Update (International Society of Sports Nutrition Position stand: Nutrient Timing (J Int Society of Sports Nutr). Oct 2008 (BioMed Central)
https://jissn.biomedcentral.com/articles/10.1186/1550-2783-5-17

Nutrient Timing:

Resistance Training Considerations:

- Prior to exercise: CHO, PRO and creatine enhance training adaptations and decrease muscle damage (measured as creatine kinase and myoglobin, 3-methyl histidine)

As glycogen diminishes see:

- decreased exercise intensity,
- muscle tissue breakdown
- immune suppression

- During Resistance Training – consuming 6% CHO + 6% EAA – decreased cortisol rise (7% vs 105% in placebo group and muscle damage (urinary 3-methyl histidine).

- Ideal appears to be every 15 minutes during a 2-hour resistance training to slow muscle catabolism, and to improve post-exercise glycogen stores, and lean mass gains (cross-sectional density) and decrease lean mass catabolism.

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

The Addition of Creatine

- Adding Creatine to CHO + PRO supplement with regular resistance exercise produces greater improvements in strength and body composition as compared to not consuming Creatine.

-

  The addition of branched chain amino acids (BCAA) also appears to improve anabolic effect.

Endurance Training Considerations:

New Glycogen Loading Approach For Endurance Events:

- 5-7 days prior to competition, increase CHO to 70% calories and decrease training intensity and duration (600-1000 grams/day or 8-10 gm/kg/d)
- Traditionally – glycogen depletion (with exercise to exhaustion approach and low CHO diet) 3-6 days prior to increasing CHO intake. 1-3 days prior go high CHO to maximize glycogen stores

3-4 Hours Prior to Training or Competition:

- 1-2 gm CHO/kg and 0.15-0.25 gm PRO/kg (Example: for me: 120 gm CHO = 480 calories + 40 gm protein = 160 calories – Total 520 calories (plus a bit of healthy fat 5gm {45 calories} = 565 calories in total.

30 Minutes Before Exercise

- Used to just recommend fructose to prevent glycemic and insulin response.
- More Recently: CHO + Protein + Fat = deceased muscle damage (Creatine Kinase blood levels), improved performance (endurance and power – vertical jump and reps at 80% RM), and increased anabolic environment (growth hormone and free testosterone) during and after exercise bouts.
- 3:1 or 4:1 ratio of CHO to Protein is standard, along with some creatine.

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

During Aerobic Exercise

- Consume only water for first 60 mins (up to 90 mins)

- During Intense Exercise – 10-15 fl oz of CHO/electrolyte solution delivering 6-8% CHO, using combination of glucose, fructose and maltodextrins, but fructose should be minimal as can cause GI upset due to slower absorption rate (causing higher gut osmolarity – diarrhea, cramps etc.) So, a 2:1 glucose to fructose ratio often used. Also a gel or drink containing 1:3 or 1:4 CHO:Protein ratio appears to:

- This strategy better promotes glucose oxidation with higher output (note that glucose only 1.0 gm per minute vs glucose, maltodextrin and fructose – up to 1.5gm – and up to 1.75 gm/min of glucose oxidation – increased sustained power

- Slow glycogen depletion (liver) – with PROTEIN added

- Decrease muscle catabolism – with PROTEIN added

GLOBAL
INTEGRATIVE MEDICINE ACADEMY

- Addition of protein to CHO replenishment drinks also aids in 2nd bout exercise (tournament days or back to back days of competition).

- Addition of PROTEIN to CHO drink improves protein balance (nitrogen balance) compared to no protein.

- Adding a small amount of fat during long, endurance training may blunt the glycemic response and be beneficial from that standpoint.

After Exercise

- 6-12 gm Essential Amino Acids and 30-60 gm CHO (high glycemic) within 3 hours after exercise and immediately before exercise have been shown to stimulate muscle protein synthesis

Daily post-exercise ingestion of CHO + PRO supplement promotes:

- Greater increase in strength
- Improvements in Lean Mass
- Decrease body fat percentage
- Often use a 3:1 or 4:1 CHO:PRO ratio providing 1.2-1.5 gm/kg CHO of simple CHO (dextrose, sucrose) with 0.3 – 0.5 gm/kg of high quality PRO containing EAA.

- Whey protein is absorbed faster and shown to increase protein synthesis

- Casein protein may help to slow muscle catabolism because it is absorbed more slowly

- Athletes who ingest 1.5 gm CHO/kg body wt, within 30 minutes after exercise see greater glycogen re-synthesis that if CHO intake delayed by 2 hours, largely due to greater insulin sensitivity of glycogen synthase enzyme immediately after exercise.

- Both solid and liquid CHO replenishment after exercise gives equal glycogen re-synthesis benefit, but fructose is less effective due to reduced insulin response.

- Delaying CHO ingestion for 2 hrs after exercise decreases glycogen re-synthesis by 50% compared to immediate replenishment after exercise.

- Ideally, 0.6-1.0 gm CHO kg per hour during first 30 minutes, and again every two hours for 4-6 hours, can adequately replenish greatly depleted glycogen stores. (tournament days and back to back competition days)

- Practical Approach – 8g/kg/day can replenish daily glycogen depletion and restore glycogen in 24 hours if practiced on a daily basis. (example for me: 90 x 8= 720 gm, which is 4x720 = 2880 calories per day from CHO if I am training hard.)