Macronutrients
Metabolism in
Exercise & Training
HNF 610: Nutrition & Fitness
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Fuel for Exercise

- The fuel mixture that powers exercise generally depends on:
  - The intensity of effort
  - The duration of effort
  - The exerciser’s fitness status
  - The exerciser’s nutritional status
The Energy Spectrum of Exercise

- ATP and PCr supply most of the energy for exercise.
- ATP-PCr and lactic acid systems provide $\frac{1}{2}$ of the energy required for intense exercise lasting 2 minutes.
  - Aerobic reactions provide the remainder of the required energy.
Aerobic Energy Transfer

- Intense exercise
- Intermediate in duration
- 5 to 10 minutes
- Examples:
  - Middle distance running
  - Swimming
  - Basketball
Aerobic Energy Transfer without Lactate

- Longer duration
- Requires a steady energy supply
- Examples:
  - Marathon running
  - Distance swimming or cycling
  - Jogging, hiking, or backpacking
Anaerobic Energy Transfer

- Supply energy for fast movements
- Supply energy during increased resistance to movement
- Short duration
- Example:
  - Sprinting
Sources of Energy for ATP Synthesis

- Sources of energy for ATP synthesis include:
  - Liver and muscle glycogen
  - Triacylglycerols within adipose tissue and active muscle
  - Amino acids within skeletal muscle donate carbon skeletons
Carbohydrate Use During Exercise

- Muscle glycogen and blood glucose serve as primary fuels during intense anaerobic exercise.
- Glycogen stores also play an important role in sustained high levels of aerobic exercise.
- The liver releases glucose for use by active muscle as exercise progresses from low to high intensity.
Carbohydrate Use During Exercise (cont.)

- Carbohydrate availability in the metabolic mixture controls its use.
- Carbohydrate intake affects its availability.
- Exercise intensity impacts to what degree glucose and glycogen are used as a fuel source.
Intense Exercise

- Change in hormone release
- Glycogen phosphorylase

Early in activity:
  - Stored muscle glycogen is the primary contributor.

As duration progresses:
  - Blood glucose from the liver increases its contribution.
Moderate and Prolonged Exercise

- First 20 minutes
  - Glycogen stored in active muscles
- Next 20 minutes
  - 40-50% liver and muscle glycogen
  - Remainder from fat breakdown
- As exercise continues
  - Glucose from the liver becomes major contributor
  - Fat use increases
Glycogen Depletion

- Blood glucose levels fall.
- Level of fatty acids in the blood increases.
- Proteins provide an increased contribution to energy.
- Exercise capacity progressively decreases.
Trained Muscle

- Trained muscle has an augmented capacity to catabolize carbohydrate aerobically for energy.
- Due to an increased oxidative capacity of the mitochondria and increased glycogen storage
- Greater fat use during submaximal exercise, less reliance on muscle glycogen and blood glucose
Gender Differences

- Women derive a smaller proportion of energy from carbohydrate oxidation than do men during submaximal exercise at equivalent percentages of aerobic capacity.
- Following aerobic exercise training, women show an exaggerated shift toward fat catabolism, whereas men do not.
Influence of Diet

- A carbohydrate-deficient diet rapidly depletes muscle and liver glycogen.
- Low carbohydrate levels profoundly affect both anaerobic capacity and prolonged, high-intensity aerobic exercise.
- When carbohydrates are low, exercise intensity decreases to a level determined by how well the body mobilizes and oxidizes fat.

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Influences of Diet

The following diets are counterproductive for weight control, exercise performance, optimal nutrition, and good health:

- Starvation diets
- Low-carbohydrate, high-fat diets
- Low-carbohydrate, high-protein diets
Fat as an Energy Substrate

- Fat supplies about 50% of the energy requirement during light and moderate exercise.
- Stored fat becomes more important during the latter stages of prolonged exercise.
- During prolonged exercise, fatty acids provide almost 80% of the energy requirements.
Sources of Fat During Exercise

- Fatty acids released from adipocytes
  - Delivered to muscles as FFA bound to plasma albumin
- Circulating plasma triacylglycerol bound to lipoproteins as very low density lipoproteins and chylomicrons
- Triacylglycerol within the active muscle itself
Lipolysis

- Hormones activate lipase.
  - These hormones are secreted more during exercise.
- Mobilization of FFAs from adipose tissue
- Trained muscle has an increased activity of adipose tissue lipases.
Hormones

- Hormones influence substrate:
  - Availability
  - Mobilization from body tissue stores
  - Uptake at tissue site of utilization
  - Uptake within tissue itself
  - Trafficking among storage, oxidation, and/or recycling
Exercise Training and Fat Metabolism

- Regular aerobic exercise:
  - Facilitates the rate of lipolysis
  - Increases the ability to oxidize long-chain fatty acids
  - Improves the uptake of FFAs
  - Increases muscle capillaries and the size and number of muscle mitochondria
Protein Use During Exercise

- Serves as an energy fuel to a much greater extent than previously thought
  - The amount depends upon nutritional status and the intensity of exercise training or competition.
  - This applies particularly to branched-chain amino acids that oxidize within skeletal muscle rather than within the liver.
Protein Use During Exercise (cont.)

- Exercise in a carbohydrate-depleted state causes significant protein catabolism.
- Protein synthesis rises markedly following both endurance- and resistance-type exercise.
Protein Requirements

- Re-examining the current protein RDA seems justified for those who engage in heavy exercise training.
- One must account for increased protein breakdown during exercise and the augmented protein synthesis in recovery.