

Chapter 3

- Part 2

Factors that affect which fuel is used

- When _____ increases, carbohydrates become more important for energy production.
 - Classic: Only _____ are used at intensities greater than 95% VO₂max
 - It is possible that intramuscular triglycerides are used at high intensities as well.
 - ...but, the take home point is _____ are the principle fuel at high intensities.

Effect of Exercise Intensity on Muscle Fuel Source

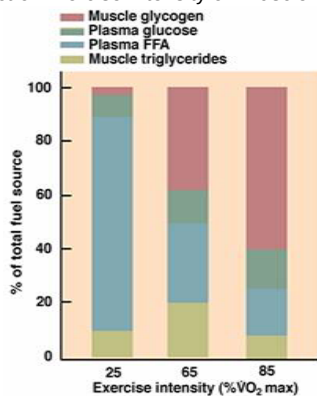
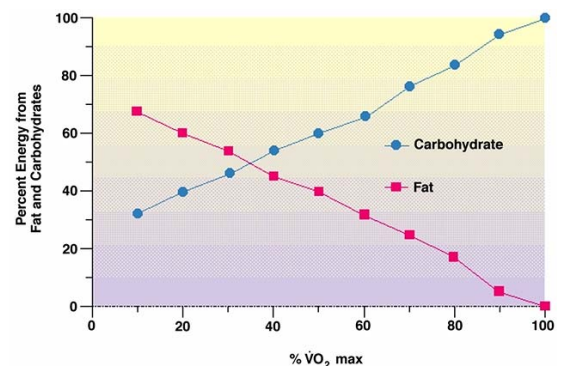
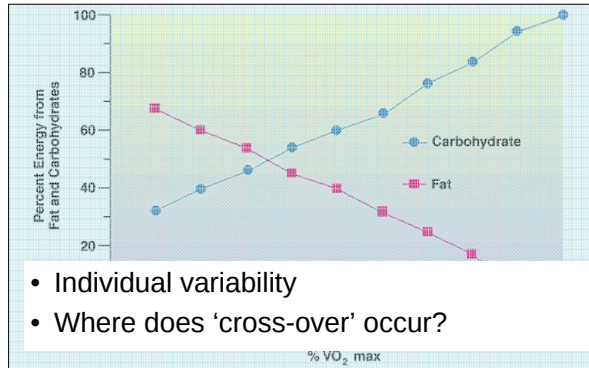


Fig 4.14

Intensity



Intensity



Variability

- Individuals can respond uniquely.
 - Noakes: not all subjects were able to complete a 3-hour bout of exercise after carboloading without some carbohydrate during exercise.
 -

Estimation of Fuel Utilization During Exercise

- Respiratory exchange ratio (RER or R)
 - $V\text{CO}_2 / V\text{O}_2$
- Fat (palmitic acid) = $\text{C}_{16}\text{H}_{32}\text{O}_2$
- $$\text{C}_{16}\text{H}_{32}\text{O}_2 + 23\text{O}_2 \rightarrow 16\text{CO}_2 + 16\text{H}_2\text{O} + ?\text{ATP}$$
- $$R = V\text{CO}_2 / V\text{O}_2 = 16 \text{ CO}_2 / 23\text{O}_2 = \underline{\hspace{2cm}}$$
- Glucose = $\text{C}_6\text{H}_{12}\text{O}_6$
- $$\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + ?\text{ATP}$$
- $$R = V\text{CO}_2 / V\text{O}_2 = 6 \text{ CO}_2 / 6\text{O}_2 = \underline{\hspace{2cm}}$$

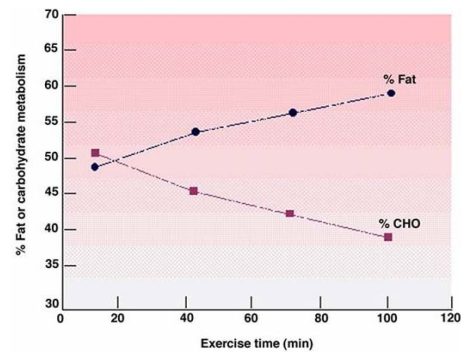
Estimation of Fuel Utilization During Exercise

- Indicates fuel utilization
 - 0.70 = 100% _____
 - 0.85 = 50% fat, 50% _____
 - 1.00 = 100% _____
- During steady-state exercise
 - $V\text{CO}_2$ and $V\text{O}_2$ reflective of O_2 consumption and CO_2 production at the cellular level

Variability

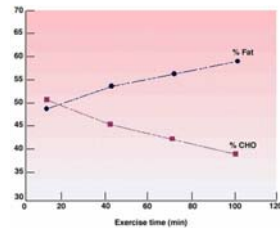
- Factors that influence variability in usage of fuel:
 - Muscle glycogen levels
 - Proportion of Type I fibers
 - Resting blood free fatty acids
 - Lactate concentrations
 - Percentage of dietary fat intake
- Not all athletes are metabolically the same.

Duration



Duration

- As _____, fat becomes an important fuel source.
 - The contribution of muscle glycogen reduces.
 - Liver glycogen (and hence blood glucose) also become depleted with duration.
- Practical point: It is important to take in _____ during long durations.



Effect of Exercise Duration on Muscle Fuel Source

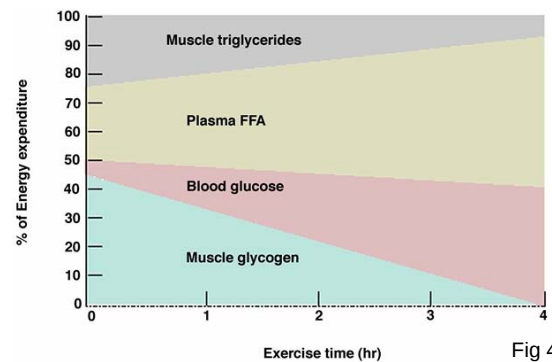


Fig 4.15

Factors affecting usage of food

- Fitness
 - Classic: _____ reduces the amount of carbohydrate used during exercise.
 - Alternative:
 - Increased fitness leads to _____ of fat oxidation at low intensities
 - Above _____, fitness leads to increased capacity to use blood glucose

Factors affecting usage of food

- _____ stores
 - There is a relationship between pre-exercise muscle glycogen concentrations and duration of exercise (_____).
 - Experimental limitation: Duration vs. distance
 - Is the cause of fatigue reduced muscle glycogen or something else?
 - Inc. body temp, SSC fatigue, liver glycogen, placebo?

Factors affecting usage of food

- What was last eaten and when?
 - Low levels of _____ levels are associated with fatigue.
 - Attempts have been made to understand how to preserve muscle glycogen.
 - e.g., Alter pre-race diet to increase reliance on fat metabolism.
 - It is not possible to _____ by altering pre-race diet.
 - _____ ingested before exercise increases the amount of carbohydrate used during exercise.
 - Refueling during race is critical to preserving muscle glycogen (and liver glycogen) levels.

Factors affecting usage of food

- Ingesting Caffeine and Fat
 - _____ appears to have no metabolic value during exercise.
 - Possibly because caffeine loses its ability to mobilize fat when someone has carbo-loaded.
 - Caffeine does seem to _____ time to exhaustion.
 - Benefit could come as much as 4 hours after ingestion
 - _____ (a cup of coffee has about 40 – 100 mg)
 - 80 kg person would need about 3-6 cups of coffee
 - More than 9 mg/kg can increase negative side effects
 - Could be due to _____ effect vs. metabolism effect.
 - Supports the idea of Integrated Neuromuscular Recruitment Model.
 - Could be due to influence on muscle cell
 - Increase release of calcium?
 - Individual tolerance levels

Factors affecting usage of food

- Ingesting a _____ Meal
 - Eating a high-carb meal pre-exercise will increase the amount of carbs used during exercise.
 - Classic: Eating high-carb meal pre-exercise was not recommended because this might increase insulin levels.
 - Insulin is a hormone that controls the uptake of sugars, proteins and fats.
 - Insulin functions to lower blood glucose levels; therefore, one should not exercise with elevated insulin levels.
 - Contemporary: Not all carbohydrates are equal.
 - Carbs with high _____ cause a rapid rise in blood glucose concentrations. Release of insulin is stimulated.
 - Carbs with low GI cause a smaller, more delayed rise in blood glucose (and therefore less insulin response).
 - » Probably a good idea to have carbs with low vs. high GI pre-exercise.

Ingesting a High-Carbohydrate Meal

- Ingesting food 45 min – 4 hours before exercise might enhance performance.
 - There is a lot of variability in how people respond to eating pre-exercise and during exercise.
 - Practice nutrition plan
 - The effectiveness of the pre-exercise meal may be dependent on during-exercise use of carbs.
 - Prevent depletion of liver glycogen.

Factors affecting usage of food

- _____ Concentrations
 - B-group vitamin that inhibits fat mobilization.
 - Used to treat high-blood cholesterol.
 - Found in meat, wheat germ, dairy products, and yeast
- Fasting Before Exercise
 - Fasting increases _____ levels in blood.
 - However, performance is impaired due to _____.

Factors affecting usage of food

- Taking in fuel during exercise
 - _____ taken in during endurance exercise does not reduce overall rate of muscle glycogen use.
 - ...but maybe reduced rate in Type I fibers
 - During _____ exercise, glucose intake may spare muscle glycogen.
 - Glucose taken in during endurance exercise spares liver glycogen levels.
 - Ingested carbohydrate serves as a substitute for glucose released by the liver.

Factors affecting usage of food

- The Athlete's Regular Diet
 - High-carbohydrate
 - Long thought to be necessary for optimal endurance performance.
 - High-fat
 - > 50% of daily calories from fat
 - Athletes may be able to adapt to this type of diet with no detrimental effects on performance.
 - ...no convincing evidence that performance is enhanced.
 - Comparative nutrition: Endurance animals perform better on high-fat vs. high-carb diet.
 - Take home point: A variety of diets can be used that do not negatively influence performance.
 - ...but, this must be a regular diet.

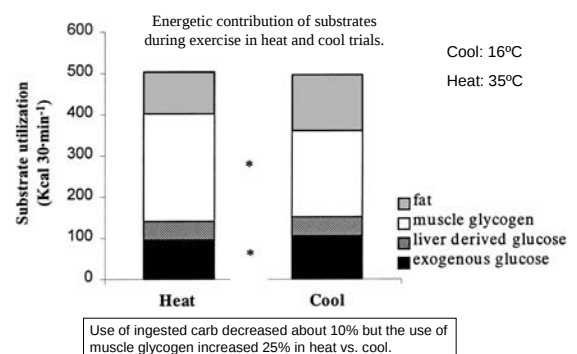
Factors affecting usage of food

- Gender
 - Women use _____ as a fuel during exercise intensities between 65% and 75% VO₂max.
 - It is not clear if this offers an advantage.
 - During race carbo loading strategies should keep this in mind.

Factors affecting usage of food

- Environmental temperature
 - The rate of muscle glycogen use _____ in the heat.
 - Carb ingestion aids performance but only when _____ is managed.
 - _____ problems increase with carb ingestion during heat.
 - Carb intake may need to be reduced in heat (50-60 g/hr vs. 60-70 g/hr).

Jentjens, Wagenmakers, and Jeukendrup (2002). Heat stress increases muscle glycogen use but reduces the oxidation of ingested carbohydrates during exercise. *Journal of Applied Physiology*, 92, 1562-1572.



Factors affecting usage of food

- Warming Up
 - Warm up does not slow the rate of muscle glycogen use during exercise.
 - Warm up does increase blood flow to muscles and temperature of active muscles.

Section Summary

- Energy
- Fuels
 - Carbohydrates
 - Fats
 - Proteins
- Factors affecting usage of food
 - Intensity
 - Duration
 - Fitness
 - Diet
 - Carbohydrate stores
 - What was last eaten and when
 - Ingesting caffeine and fat
 - Ingesting a high-carb meal
 - Nicotinic acid concentrations
 - Fasting before exercise
 - Taking in fuel during exercise
 - The athlete's regular diet
 - Gender
 - Environmental temperature
 - Warming up
 - Increasing carbohydrate stores before exercise

Central Governor's Role During Prolonged Exercise

- Ingesting carbohydrate during exercise _____ time to exhaustion.
 - Blood glucose levels were maintained at exhaustion.
 - This means that _____ was not caused by low blood glucose levels.
 - Rate of carbohydrate oxidation and muscle glycogen concentrations remained unchanged.
 - Why did exhaustion occur at 4 hours instead of 3 hours when metabolic profile remained unchanged?

Central Governor's Role During Prolonged Exercise

- _____ is the point where work can no longer be accomplished.
 - Fatigue leads to exhaustion
 - Where did fatigue occur?
 - Constant work load
- Another experimental model is to have subjects complete _____ as possible.
 - Have subjects complete sprint trials at specific distance intervals.

Central Governor's Role During Prolonged Exercise

- What is the significance of reduced muscle recruitment?
 - Prevent muscle glycogen depletion, muscle rigor, hyperthermia, heat-stroke, ...?
- Examining Figure 3.19, maybe the central governor allows exercise of about _____ to continue up to 4 hours before exercise intensity has to be decreased.
 - We don't know if subjects could have continued to exercise at a lower intensity.
 - However, if _____ develops, there is a earlier need to reduce muscle recruitment.

Fatigue

- General tiredness.
- Classic: _____.
- Noakes: Physical manifestation of a change in pacing strategy.
 - Pacing is the key to success at endurance performance.
 - Fatigue and exhaustion are different concepts.
 - When one is fatigued, exercise can continue but at a lower intensity.
 - When one is exhausted, exercise cannot continue.
 - When pacing slows, maybe what is happening is the body is simply maintaining homeostasis.
 - Prevent rigor, myocardial ischemia, maintain body temperature, ...
- _____.

Preventing Hypoglycemia

- Hypoglycemia (low levels of _____) is preventable and reversible.
 - e.g., drinking a liter of coke (about 100 g carbohydrate)
- _____ is more likely the longer the race.
 - 2% of runners in 42-km marathon
 - 6% @ 56 km
 - 11% @ 90 km
- At marathon pace (~85% VO₂max):
 - Muscle glycogen stores can last ~2 hours.
 - Liver glycogen stores can last ~2 – 2.5 hours.
- At ultramarathon pace (~70-75% VO₂max):
 - Muscle glycogen stores can last ~4-4.5 hours.
 - Liver glycogen stores used at about the same rate as marathon pace.
 - If carbs are not replaced during long duration races, hypoglycemia will result.

Carbohydrate Ingestion During Exercise

- Carbohydrate ingestion during prolonged exercise reduces the perception of fatigue while also delaying fatigue and increasing performance.
- Carbohydrate ingestion needs to occur throughout a race.
 - Carb ingestion near end of race not effective.
- Carbohydrate ingestion does not reduce the rate of muscle glycogen use but does _____ stores.
- Carbohydrate ingestion is most important for endurance events > 2 hours.
 - However, maybe some positive influence at short (~1-hour), high intensity exercise.
 - But this is not due to prevention of hypoglycemia.

Type and Amount of Carbohydrate

- Most forms of carbohydrate are able to supply glucose to the bloodstream if ingested at rates of about 60 – 90 g per hour.
- Recommendations:
 - ~40-80 g per hour (typical target 60 g/hr)
 - Rate of use is ~1 g per min
 - Any palatable carbohydrate
 - Solid or liquid

Restocking Glycogen

- Eat high-carb diet post exercise
 - Do athletes really eat high-carb diet?
 - 8 g carbohydrate per kg body weight must be eaten daily.
 - 80 kg athlete » 640 g carbohydrate
 - 16 cans of coke
 - 30 apples
 - 10-20 bagels
- Glycogen resynthesis not influenced by solid or liquid nature of carbohydrate.
- Ingestion should begin immediately after exercise.
 - 50 – 80 g repeated 30-60 minutes and continuing for 5-6 hours.