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.
Intensity

- Individual variability
- Where does ‘cross-over’ occur?

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)
  - VCO₂/VO₂

Fat (palmitic acid) = C₁₆H₃₂O₂
  \[ \text{C₁₆H₃₂O₂ + 23O₂} \rightarrow 16\text{CO₂} + 16\text{H₂O} + \text{?ATP} \]
  \[ R = \frac{\text{VCO₂}}{\text{VO₂}} = \frac{16 \text{ CO₂}}{23 \text{ O₂}} = \underline{？} \]

Glucose = C₆H₁₂O₆
  \[ \text{C₆H₁₂O₆ + 6O₂} \rightarrow 6\text{CO₂} + 6\text{H₂O} + \text{?ATP} \]
  \[ R = \frac{\text{VCO₂}}{\text{VO₂}} = \frac{6 \text{ CO₂}}{6 \text{ O₂}} = \underline{？} \]

Estimation of Fuel Utilization During Exercise

- Indicates fuel utilization
  - 0.70 = 100% \underline{？}
  - 0.85 = 50% fat, 50% \underline{？}
  - 1.00 = 100% \underline{？}

- During steady-state exercise
  - VCO₂ and VO₂ reflective of O₂ consumption and CO₂ 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

• 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.
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.
      - Refusing 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 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

- 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 GI 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.

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Factors affecting usage of food

- _________________ Concentrations
  - B-group vitamin that inhibits fat mobilization.
  - Used to treat high-blood cholesterol.
  - Found in meat, whet germ, dairy products, and yeast

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Factors affecting usage of food

- Fasting Before Exercise
  - Fasting increases _________________ levels in blood.
  - However, performance is impaired due to _________________.
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.

- 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.

- 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).


Energetic contribution of substrates during exercise in heat and cool trials.

Use of ingested carb decreased about 10% but the use of muscle glycogen increased 25% in heat vs. cool.
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
  – Intensity
  – Duration
  – Fitness
  – Diet
  – Carbohydrate stores
  – What was last eaten and when
  – Ingesting caffeine and fat
  – Ingesting a high-carb meal
  – Nicotinic acid concentrations

• Fuels
  – Carbohydrates
  – Fats
  – Proteins

• Factors affecting usage of food
  – 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)

• It 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.