Lore of Running

Chapter 3

Energy

• Different Forms
  • Nuclear
  • Heat
  • Mechanical
  • Chemical
  • Light Electrical

The capacity to do work.

– Units:

• Work (thermodynamics) is the transferring of energy from one object to another
  – Mechanical work:

Calorie

• Calorie
  – ___________

  – 1 Calorie = 4184 J
  • Large calorie … kcal

  – The amount of _____ needed to change the temperature of 1 kg water (1 L) from 14.5º C to 15.5º C.
  • If the energy were released of a substance with a caloric value of 300 Calories …
    – The temperature of 300 L of water would be raised 1º C

Energy

• Food is ___________

  • A piece of buttered toast has about 315 kJ (~75 Calories) of energy.
    – Jog for 6 minutes
    – Bike for 10 minutes
    – Light a 60 W light bulb for 1.5 hours
How the body uses food

- **Digestion**

  - The process by which food is broken down ________ and ________ in the gastrointestinal tract and converted into absorbable forms.

  *Taber's*

- **Mouth**

- **Stomach**

  - Some small molecules (e.g., alcohol) can be absorbed into __________.

- **Small intestines**

  - The majority of ________ and absorption takes place here.

  - Secretions from liver and pancreas

  - Fats, and proteins absorbed in upper/middle parts of small intestine.

- **Large intestines**

  - Cecum, colon (ascending, transverse, descending, rectum)

- **Carbohydrate**

  - Composed of __________.

  - Three types

    - More than 200 monosaccharides
      - Glucose, fructose, galactose

    - Disaccharides
      - Combination of two monosaccharide molecules
        - Sucrose: glucose + fructose
        - Lactose: glucose + galactose
        - Maltose: glucose + glucose
      - Simple sugars
        - e.g., brown sugar, corn syrup

    - Three or more simple sugar molecules
      - Starch
      - Fiber
      - Glycogen
Carbohydrates

• Absorbed carbohydrates transported to _____.
• ______ can be stored as glycogen in liver or transported to skeletal muscle (muscle glycogen).
  • Glyconeogenesis: Formation of glycogen from noncarbohydrate sources
    – Glycogen is the only form carbohydrates are stored.
• Glucose is used by ______, kidney, red blood cells
• Glycogen stored in liver can be broken down to glucose and delivered at a rate of about 10 g per hour at rest and 60 g per hour during exercise.
  • Glycogenolysis: Breakdown of glycogen to glucose

Hypoglycemia

• Low levels of glucose in blood
• History
  – 1924 Boston Marathon
    • Postrace blood glucose concentrations were decreased in all runners.
    • Runners with low blood glucose levels presented with “asthenia, pallor and prostration.”
    – Loss of strength, lack of color, absolute exhaustion
    • Following year runners used high-carbohydrate pre-race meal
  • Harvard Fatigue Lab
    • Dogs (Joe and Sally) ran without exhaustion for 24-hours when fed sweets
    • Without, both became exhausted
• Related to fatigue

Fats

• Three groups
  – ______
    • Triglycerides: the most plentiful fat in the body (~95% of fat in body)
      – Three fatty acid molecules attached to one glycerol molecule
  – ______
    • Simple fat combined with other chemicals
      – E.g., lipoproteins (transport fat in blood)
  – ______
    • Fats derived from simple and compound fats
      • e.g., cholesterol

Fat

• Digested in ___________ intestines
  – enzymes from pancreas
• Stored as ___________
  – adipose tissue and in muscle
  – To be used as energy
  • fatty acid must be separated from glycerol molecules
  • Free fatty acids and glycerol transported via circulatory system (carrier: albumin)
Protein

- Greek: ‘of prime importance’
- Combinations of __________ make up proteins
  - 20 amino acids required by the body
  - 8(9) cannot be synthesized in the body (i.e., essential)
- Digested to yield ___________.
  - Amino acids transported to liver.
  - Used as an energy source during prolonged exercise (e.g., > 3 or 4 hours)
  - ~2-8%

Limits to Performance

- __________
  - Performance is limited by the availability of substrate and capacity of metabolic pathways
  - Anaerobic
  - Aerobic
  - Superior endurance performance is a function of being able to produce ATP __________.
    - Fatigue would result by the breakdown of the metabolic pathway (e.g., lack of available substrate)
      - ATP would not be produced
      - Rigor would result
    - Noakes questions the validity of this argument
      - ATP levels are protected since ATP levels do not drop below 60% of resting levels.

Limits to Performance

- Central Governor Model: Reduced muscle recruitment

How the body stores fuel

- ______ accounts for up to 64% of total body weight.
- ___ is the largest energy store in the body.
  - Carbohydrate stores are relatively small.
    - If only carbohydrate was used as a fuel during a marathon, the storage would last about 2 hours (fat: 59 hours).
Carbohydrate Storage

- The amount of ____________ that can be stored varies between people
  - Influenced by training
    - Untrained: 280 g
    - Trained: 720 g
  - Influenced by _____
    - Table 3.1

Factors Affecting Fuel (Carbohydrate) Storage

- Carbohydrate storage is greater for trained vs. untrained people.
  - Deplete
  - Diet
  - Replenish

Storage

- _______
  - Body composition for endurance runners
    - Lower %body fat: e.g., 4-7%
- _______
  - Are present in all cells
    - Cell walls, filaments, structural, compounds in blood ...
    - Protein storage is tightly regulated
      - Weight lifting
    - Starvation leads to a reduction in protein stores.
Factors affecting depletion of carbohydrates

• Exercise _____________________
  – The higher the intensity, the more rapid rate of glycogen use.
  – Continuous exercise at ______ VO2max for periods longer than 2 hours results in the greatest muscle glycogen depletion.

Diet

• Eating a ________________ diet
  – Glucose produced by liver is used to return blood glucose and muscle glycogen stores back to normal.
  – The resynthesis of ______ is aided by a high-carbohydrate diet.
  – Does a pre-race carbohydrate depletion/replenishing program work?
    • Figure 3.7

• Figure 3.8 Rates of liver and muscle glycogen as a function of exercise intensity and duration.

• Group A:
  – Exercised to exhaustion (day -3)
  – Ate high-fat-protein, low carb for 3 days
  – Exercised to exhaustion
  – Ate high carb diet for 7 d

• Group B:
  – Exercised to exhaustion (day -1)
  – Ate high-fat diet (1 day)
  – Exercised to exhaustion (day 0)
  – Ate high carb diet for 7 d

• Group C
  – Exercised to exhaustion (day 0)
  – Ate high-carb diet for seven days
• Key points:
  – _____________________ reduced muscle glycogen levels.
  – Minimal glycogen resynthesis on high-fat-protein diet for Groups A and B (pre day 0).
  – _________ glycogen levels
    • Peaked for Group B
    • Continued to rise for Group A
  – Subjects were relatively unfit.

Carbo-loading

• Depletion / carbohydrate loading diet similar to Group A.
  – ‘carbo-loading’ pre-race parties
  – 7 days are needed
  – Subjects were unfit
• Trained athletes using different diets
  – Different manipulations of carbo/fat diets
  – The main determinants of muscle glycogen levels during carbo loading are the 1) athlete’s level of training and 2) the amount of carbohydrate eaten daily.

Figure 3.8

• Muscle glycogen levels were low in athletes when exercising to exhaustion at 60-80% VO2max.
  – Hypothesis: Low levels contribute to fatigue
• Athletes on ______ diet had lower exercise performance than those on high-carbohydrate diet.
  – Starting level of ______ glycogen lower for high-fat diet.
• Athletes who carbo loaded out performed those who did not.
  – Observation: There is a _______ relationship between pre-exercise muscle glycogen and duration of exercise.
• Hypothesis: Superior endurance performance resulted from higher pre-exercise muscle glycogen levels which delayed exhaustion (onset of muscle glycogen depletion).
**Challenges**

- There is no direct evidence that any one phenomenon (e.g., muscle glycogen depletion) causes exhaustion.
  - The model is based upon the association of muscle glycogen and exhaustion.
  - There may be some other phenomenon that happens at the same time as muscle glycogen depletion.
    - Reduced blood glucose concentration (liver glycogen depletion leads to hypoglycemia)
    - Rising body temperature
    - Stretch-shortening fatigue
    - Central fatigue
    - Placebo effect
  - ATP depletion is not present at exhaustion.
  - ...which means ATP is available (i.e., rigor is not present).

- The key to carbo loading may be the three days of carbohydrate depletion.
  - Does this pre-program the Central Governor to accept lower blood glucose concentrations?
  - Evidence building that athletes can adapt to different diets (e.g., high-fat) without sacrificing endurance performance.
  - The hypothesis that exhaustion occurs at low muscle glycogen levels is not tenable for athletes who have adapted to a high-fat diet.
Carbohydrate

- Having a sufficient level of ________ is important to endurance performance.
- The mechanism of ________ is not known.
- It is not clear what role pre-exercise muscle glycogen levels plays in fatigue.
  - Low levels during exercise may trigger some other mechanism that leads to fatigue.
  - Low levels during exercise does not always lead to fatigue.