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

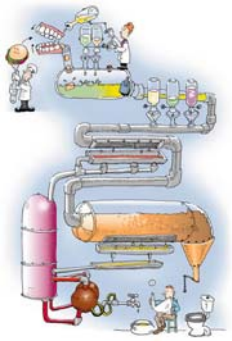
- Calorie
  - _____
  - 1 Calorie = 4184 J
    - Large calorie … kcal
  - The amount of ____ needed to change the temperature of 1 kg water (1 L) from 14.5º C to 15.5º C.
    - If the energy were released of a substance with a caloric value of 300 Calories …
      - The temperature of 300 L of water 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



Digestion

- 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
  - _____

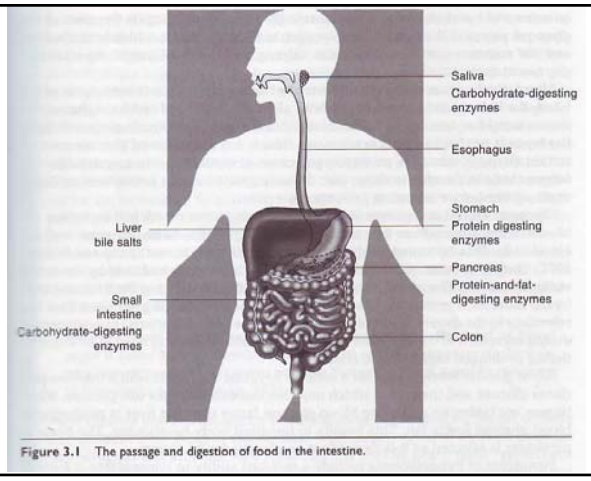


Figure 3.1 The passage and digestion of food in the intestine.

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
  - _____: Formation of glycogen from carbohydrate 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 feed 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

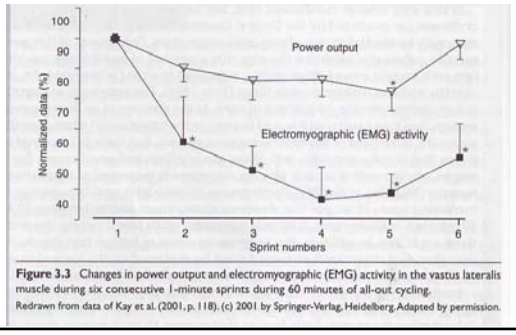


Figure 3.3 Changes in power output and electromyographic (EMG) activity in the vastus lateralis muscle during six consecutive 1-minute sprints during 60 minutes of all-out cycling.
Redrawn from data of Kay et al. (2001, p. 118). (c) 2001 by Springer-Verlag, Heidelberg. Adapted by permission.

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).

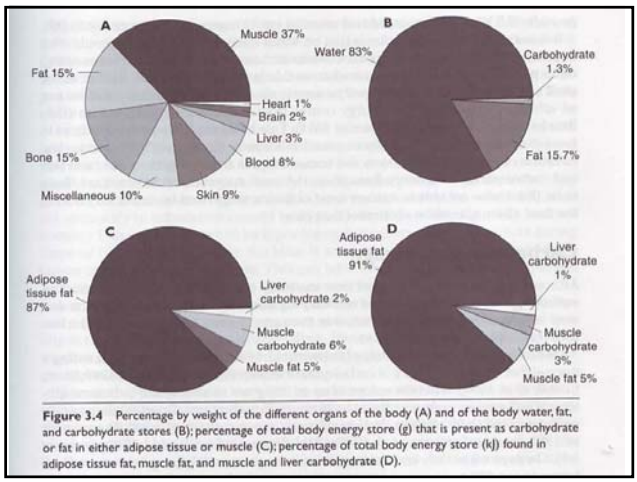


Figure 3.4 Percentage by weight of the different organs of the body (A) and of the body water, fat, and carbohydrate stores (B); percentage of total body energy store (g) that is present as carbohydrate or fat in either adipose tissue or muscle (C); percentage of total body energy store (kJ) found in adipose tissue fat, muscle fat, and muscle and liver carbohydrate (D).

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

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 Fuel (Carbohydrate) Storage

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

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.

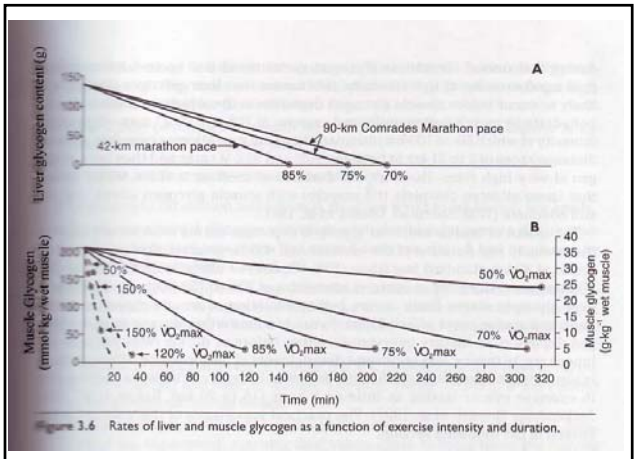


Figure 3.6 Rates of liver and muscle glycogen as a function of exercise intensity and duration.

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

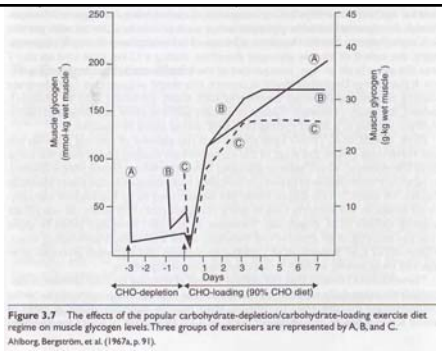


Figure 3.7 The effects of the popular carbohydrate-depletion/carbohydrate-loading exercise diet regime on muscle glycogen levels. Three groups of exercisers are represented by A, B, and C. Ahlborg, Bergström, et al. (1967a, p. 91).

- 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

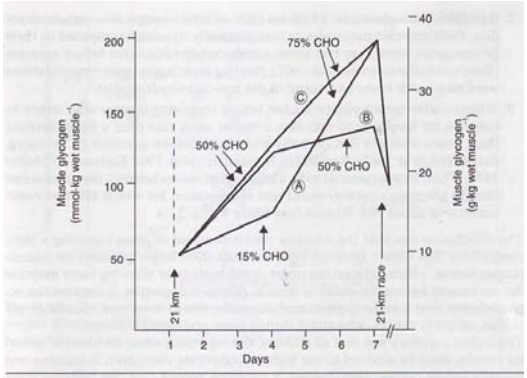


Figure 3.8 Muscle glycogen changes in trained athletes undergoing the modified carbohydrate (CHO)-loading regime.
From Sherman, Costill, et al. (1981, p. 116)

_____

- 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).

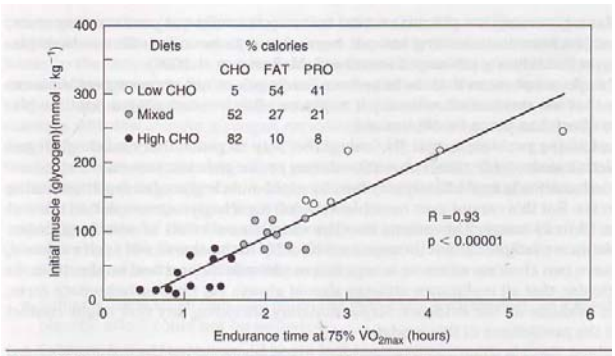


Figure 3.9 The linear relationship between preexercise muscle glycogen concentrations and exercise duration at 75% $\dot{V}O_2$max.
Adapted from data in Hermansen, Hultman, et al. (1967).

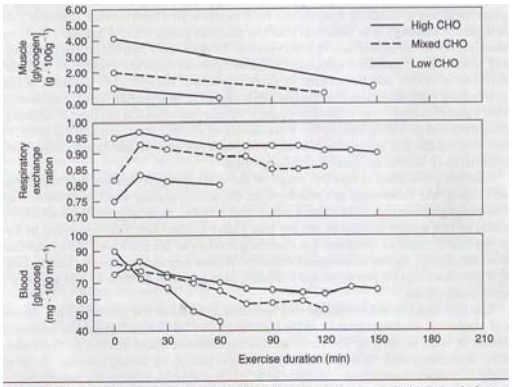


Figure 3.10 Hypoglycemia occurs rapidly in subjects eating a low-carbohydrate diet before exercise.
Data from Bergström, Hermansen, et al. (1967).

Challenges

- There is no direct evidence that any one phenomenon (e.g., muscle glycogen depletion) causes _____.
  - 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).

Challenges

- 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 dies (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.

End