Anaerobic and Aerobic Training Adaptations

Chapters 5 & 6
Adaptations to Training

- Chronic exercise provides stimulus for the systems of the body to change
- Systems will adapt according to level, intensity, and volume
Factors that Affect Adaptations to Training

- Specificity of training (figure 1)
  - Metabolic differences (aerobic vs. anaerobic) activities
  - Metabolic differences within an activity
- Genetic endowment
  - Fiber type patterns
  - Somatotype (Ecto, Meso, Endo)
- Environmental factors
Factors cont’

- Fitness training status
  - Time course of adaptations
  - Magnitude of expected changes
  - Mechanism of adaptations
- Gender
  - Mechanism of adaptations
- Age
  - Children vs. adults vs. older adults
Metabolic Contributions to Exercise Training

- Anaerobic metabolism (figure 2)
  - High intensity, short duration exercise = energy PRIMARILY from stored phosphagens and ATP
  - Stored phosphagens (creatine phosphate, CP) are molecules w/ high energy chemical bonds that when broken down, provide energy for immediate use
  - Anaerobic glycolysis (figure 2) utilized at beginning of sustained exercise (regardless of intensity)
Metabolic Contributions cont’

- Aerobic metabolism
  - Most of energy (50+%) needed for prolonged exercise lasting more than about 3 min.
  - Krebs Cycle (figure 3) degrades acetyl CoA into CO2 and H+ ions and electrons (More ATP Produced)
  - Electron Transport Chain receives electrons for Krebs Cycle and used for oxidative-phosphorylation and regeneration of ATP
  - Also, free fatty acids enter the mitochondria and undergo beta oxidation in the Krebs Cycle (fats yield the most energy)
Metabolic Contributions cont’

- Relative contribution of aerobic & anaerobic systems (figure 4A and 4B)
  - All energy systems are active at a given time
  - Extent to which energy system is used depends on:
    - Intensity (primary)
    - Duration (secondary)
Adaptations Following Exercise Training

- Neuromuscular adaptations (figure 5)
  - Neural adaptations due to:
    - Changes occurring in activation of motor unit
    - Improved recruitment patterns
    - Improvement in neural drive
    - “Learning” how to perform the activity
  - “Disinhibition” also one of the limiting factors in the development of muscular force, serving as a protective mechanism
    - Golgi tendon organ (GTO)
      - Exercise training may lead to a reduction in the sensitivity of these receptors to allow for greater force production
  - Exercise training may also lead to increased # of vesicles that store acetylcholine to allow for greater amount of neurotransmitter secretion at the neuromuscular junction and allow for greater force production
Adaptations Following cont’

- Muscle fiber type adaptations
  - Normal recruitment pattern: (Type) I → IIa → IIb
  - Exercise training results in more precise and efficient mode of recruitment
    - Following training, less neural activity required to produce any level of submaximal force measured by EMG
    - Following training, increased synchronization of motor unit firing increases the amount of time that maximal force output can be sustained
    - Fiber “transformation” (IIb → IIa) may also result in increased or altered recruitment patterns
Adaptations Following cont’

- Muscle fiber type adaptations cont’
  - Fiber type characteristics (figure 6) and examples of sport events (figure 7)
  - Changes in fiber area (example of a staining, figure 8)
    - Type II fibers will increase in area more than Type I fibers
    - Increases in fiber area are mediated by the addition of actin and myosin myofilaments to outside of myofibril
  - Hypertrophy vs. hyperplasia
    - Research is still inconclusive in humans
    - Hypertrophy model is still most commonly supported
    - Difficulty in biopsy technique
Adaptations Following cont’

- Muscle fiber “transformations”
  - Exercise results in decrease in Type IIb fibers with a concomitant increase in Type IIa fibers
  - Type IIb fibers are “couch potato” fibers and inversely related to individuals max oxygen consumption and intensity of training stimulus
  - Type I fibers will show some percent increase after resistance training, but significantly more changes after aerobic training
  - “Transformations” based on intensity and state of training – detraining causes “reversal” of Type IIa → Type IIb
  - Mitochondrial density increases in aerobically-trained individuals
  - Enzymes (creatine phosphate and myokinase) increase due to exercise training

- Neuroendocrine adaptations
  - Amount of synthesis and storage of hormones
  - Transport of hormones
  - Time needed for clearance in tissues
  - Amount of hormonal degradation
  - Number of hormone receptors in the tissues
  - Magnitude of signal sent to cell nucleus by receptor complex
  - Interaction with cell nucleus
Adaptations Following cont’

- Endocrine responses to exercise (figure 9)
- Biochemical changes seen in skeletal muscle induced by training (list on figure 10)
- Skeletal adaptations (figure 11)
  - Bone is connective tissue that becomes mineralized to provide a rigid structure to support the muscular system
  - Bone is an active tissue and is sensitive to gravitational and muscular forces
  - Bone will adapt with exercise training
    - Increase in bone mineral density and bone matrix
    - Decrease in bone density w/ reduction of exercise
    - Rapid removal of calcium = loss of bone mineral content; occurs with immobilization after only a few weeks of bed rest
    - Osteoporosis in elderly; post-menopausal women
    - Resistance training has proven to be effective in increasing bone mineral content and bone matrix (figure 12)
Adaptations Following cont’

- **Connective tissue adaptations**
  - Related to mechanical forces created during physical activity
  - Degree of adaptation related to intensity of the exercise stimulus
  - Adaptations occur
    - At the junctions between the tendon or ligament and the bone surface
    - Within the body of the tendon or ligament
    - In the network of fascia within the skeletal muscle

- **Cardiovascular adaptations (figure 13)**
  - Increase in cardiac output due to an enhanced or improved stroke volume
    - Increase in heart weight/volume occurs primarily with aerobic training
    - Cardiac hypertrophy is characterized by an increase in the size of the left ventricular cavity and a thickening of the myocardium
Adaptations Following cont’

- Increase in cardiac output
  - Stroke volume increases
  - Greater percent of the ventricular volume that is pumped out with each beat (ejection fraction)
  - Typical values of ejection fraction
    - Average individual – 65%
    - Aerobically trained athlete – 85-90%
    - Individual with cardiovascular disease – 12%
- Max heart rate may increase or may even decrease with exercise training
  - Increase may be related to a learning effect – possibly never achieved max heart rate prior to training; can do more exercise
  - Decrease may be related to an increased vagal tone
  - Decreased resting heart rate due to more parasympathetic influence
  - Decreased heart rate at any given submaximal intensity
- Increased capillarization in tissue after training
- Increased plasma volume and total hemoglobin after training
Adaptations Following cont’

- **Respiratory adaptations (figure 13)**
  - Increased maximal exercise ventilation
  - Increased maximal oxygen consumption (VO2 max)
  - Increased tidal volume
  - Increased extraction of Oxygen (14-15% O2 in expired air after training versus 18% in untrained person)
  - Onset of blood lactate accumulation (OBLA) occurs at higher percentage of the trained person’s aerobic capacity (55% untrained vs. up to 90% trained) as a result of an increased ability to generate a high lactate level after training
Specific Adaptations from Resistance Training

- Changes in fiber area
- Hypertrophy vs. hyperplasia of muscle fibers
- Muscle fiber “transformation” – Type IIb → Type IIa fibers
- Increased high energy phosphate pool
- Improved synchronization of motor unit firing
- Improved neural function
Specific Adaptations from Aerobic Training

- Increased myoglobin content
- Increased oxidation of carbohydrates (glycogen)
  - Increased capacity for muscle to generate energy
- Increased oxygen consumption (VO2) and oxygen extraction (a-vO2 difference)
- Increased biochemical changes in Type I and II muscle fibers
- Increased heart size and efficiency
Combination of Resistance and Aerobic Endurance Training

- Combined maximal training interferes primarily with strength and power performance
Overtraining

- **Markers of anaerobic overtraining (fig. 15)**
  - Psychological effects: decreased desire to train; decreased joy from training
  - Acute epinephrine and norepinephrine increases beyond normal exercise induced levels
  - Performance decrements, although these occur too late to be a good predictor

- **Markers of aerobic overtraining (fig. 15)**
  - Decreased performance
  - Decreased percentage of body fat
  - Decreased maximal oxygen uptake
  - Decreased muscle glycogen
  - Decreased lactate levels
  - Increased muscle soreness
  - Increased sub-maximal exercise heart rate
  - Altered blood pressure and resting heart rate
Overtraining cont’

- Stages of overtraining (figure 16)
  - 1\textsuperscript{st} (no effect on performance)
  - 2\textsuperscript{nd} (probably no effect on performance)
  - 3\textsuperscript{rd} (probably decreased performance)
  - 4\textsuperscript{th} (decreased performance)