Improving Muscular Strength and Endurance

Outline
- Introduction
- Structure of Skeletal Muscle
- How Skeletal Muscle Contracts
  - Motor Neurons
  - Actin and Myosin
- Types of Contractions
- Muscle Fiber Types
- Determinants of Muscular Strength
- Trainability of Muscle
- Muscular Strength and Aging

Skeletal Muscle
- Human body contains about 600 skeletal muscles
  - 40-50% of total body weight
- Functions of skeletal muscle
  - Force production for locomotion and breathing
  - Force production for postural support
  - Heat production during cold stress
Muscle Strength and Endurance

- **Muscle Strength**
  - Maximum force a muscle can generate
  - Often measured as one repetition maximum

- **Muscle Endurance**
  - Amount of time/number of repetitions that a muscle can maintain the same force
  - Often measured via one minute push up or sit up test (for examples)

Benefits of Muscular Strength and Endurance

- Decreased incidence of chronic low-back pain
- Maintenance of strength with increasing age (rather than loss)
- Decreased losses in bone density
- Improved ability to do daily/household tasks
- Elevation in resting metabolic rate

Structure of Muscle

- Muscle, like all tissues, is made up of individual cells
- These cells are also called “fibers”
- The fibers are connected by a tough, semi-transparent tissue called fascia
- The fascia around the entire muscle is called the epimysium (outside/around) myosum (muscle)
- The epimysium at the ends of the muscle become the tendons that attach the muscle to bone
**Skeletal muscle structure**

- Endomysium: covers muscle cell
- Epimysium: covers entire muscle
- Tendon – connects muscle to bone

**Muscle Contraction – Starts with Motor Neurons**

Nervous System
Peripheral NS (as opposed to CNS)

Motor Nerves
- Autonomic Nerves
  - Smooth muscle
  - Cardiac muscle
  - Involuntary
- Somatic Nerves
  - Skeletal muscles
  - Voluntary

**Motor Neuron Initiates Muscle Contraction**

- Site where motor neuron meets the muscle cell
  - There is a small gap called the synapse or neuromuscular cleft
- Acetylcholine, a neurotransmitter, is released from the motor neuron
  - Acetylcholine binds to a receptor on the muscle cell
  - This causes electrical changes in the muscle cell called an "action potential"
  - Action potentials lead to muscle contraction
  - Several poisons work by interrupting this nerve-muscle communication
Motor Unit

- Motor unit = one motor neuron and all the muscle cells it innervates
- Innervation ratio – number of muscle cells per motor neuron – variable from muscle to muscle
- Innervation ratio is low for fine motor control (e.g., hand muscles) and high for gross motor control (e.g., big leg muscles)

How Muscle Cells Contract

- Myofibrils, the contractile elements inside a fiber, consist primarily of two proteins: Actin and Myosin
- The myosin protein has multiple arms which attach on to actin molecules
- When an action potential (from the nerve) stimulates the muscle, the myosin arms pull on the actin, shortening the muscle cell length
- Calcium is required for this process
  - Lack of sufficient calcium can lead to paralysis ("milk fever" in cows, e.g.)
How Muscles Contract: The Sarcomere

- The myosin and actin are organized into a series of units called sarcomeres.
- One sarcomere is illustrated (myosin in yellow, actin in white)

How Muscle Contracts: Sliding Filament Theory

Microstructure of Skeletal Muscle
Types of Contraction

- **Isotonic or Dynamic** – involves movement
  - Concentric “miometric”
    - Muscle shortens
    - Lifting a barbell
  - Eccentric “pliometric” or “negative”
    - Muscle lengthens during contraction
    - Lowering a barbell
- **Isokinetic**
  - Constant speed of contraction
  - Usually done on a machine

*Note, figure 5.4 may be confusing*

---

Types of Contraction

- **Isometric or Static** – no movement
  - No change in muscle length
  - Pushing against a wall

---

Types of Contraction

- Concentric contraction
- Eccentric contraction
Muscle Fiber Types

- Slow-Twitch "slow"
- Fast-Twitch glycolytic "fast"
- Fast-Twitch oxidative and glycolytic "intermediate"

Muscle Fiber Types: Slow

- Slow-Twitch – also called Type I
  - Red
  - High fatigue resistance
  - Lower force, slower speed
  - Example: soleus

Muscle Fiber Types: Fast

- Fast-Twitch Glycolytic also called Type IIb
  - White
  - Fatigue quickly
  - Highest force, highest speed
- Fast-Twitch Oxidative and Glycolytic also called Type IIa
  - Red
  - Medium fatigue resistance
  - Medium force, medium speed
Muscle Fiber Types: Properties

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Fast Fibers</th>
<th>Slow Fibers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predominant energy system</td>
<td>anaerobic combination aerobic</td>
<td></td>
</tr>
<tr>
<td>Resistance to fatigue</td>
<td>low high/moderate high</td>
<td></td>
</tr>
<tr>
<td>Speed of shortening</td>
<td>highest intermediate low</td>
<td></td>
</tr>
<tr>
<td>Efficiency</td>
<td>low moderate high</td>
<td></td>
</tr>
<tr>
<td>Force (force/CSA)</td>
<td>high intermediate moderate</td>
<td></td>
</tr>
</tbody>
</table>

Histochemical Staining of Fiber Type

- Type Ia
- Type Ib
- Type II

Fiber type differences between athletes

<table>
<thead>
<tr>
<th>Sport</th>
<th>% Slow Fibers</th>
<th>% Fast Fibers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance runners</td>
<td>70-80</td>
<td>20-30</td>
</tr>
<tr>
<td>Weight lifters and Track sprinters</td>
<td>45-55</td>
<td>45-55</td>
</tr>
<tr>
<td>Nonathletes</td>
<td>47-53</td>
<td>47-53</td>
</tr>
</tbody>
</table>

Performance = physiologic, biochemical, neurologic, and biomechanical properties
What Determines Muscular Strength?

- **Muscle size**
  - The greater the cross-sectional area of the muscle, the more force it can produce
  - Resistance training leads to increased muscle size
- **Fiber Recruitment**
  - The greater the number of recruited fibers, the greater the force (additive)
  - The greater the percentage of fast (esp. IIb) fibers, the greater the force
  - Fibers are generally recruited in order of efficiency: slow, then intermediate, then fast

Fiber Recruitment

- **“Plasticity” of Skeletal Muscle**
  - Skeletal muscle demonstrates “plasticity”, or in other words, muscle can be altered in response to removal of weight bearing forces (i.e., spaceflight, immobilization, bedrest, disuse) or to the addition of physical activity
  - Adaptations may include changes in muscle fiber size and/or biochemical machinery (e.g., enzymes)
Adaptation to Strength Training – Increased Muscle Size and Strength

Loss of Muscle Mass with Age
- Loss of lean muscle mass attributed to:
  - Hormonal changes
  - Inactivity
- Loss of lean muscle mass may impair a person’s ability to perform functional tasks

Changes in Strength With Aging
Compared to younger individuals:
  - Older individuals can achieve the same relative (%) gains in strength and aerobic capacity with resistance or aerobic training.