Muscle Structure: Classification

- Smooth
  - Spindle shaped
  - Uninucleated
- Striated
  - Cardiac
    - Autonomous system
    - Cylindrical
  - Skeletal
    - Voluntary control
    - Cylindrical
    - Striated

Muscle Structure

- Human body contains over ___ skeletal muscles
  - _____ of total body weight
- Characteristics
  - Irritability
    - Ability to respond to a stimulus
  - Ability to shorten
  - Extensibility
    - Ability to lengthen
  - Elasticity
    - Ability to return to resting length

Structures in a typical cell

Gross Structure of Muscle

- Surrounds entire muscle
- Surrounds bundles of muscle fibers
  - Fascicles
- Surrounds individual muscle fibers
Microstructure of Skeletal Muscle

- **Sarcolemma**: Muscle cell membrane
- **Myofibrils**: Threadlike strands within muscle fibers
  - Z-line, M-line, H-zone, A-band & I-band
- **Elastic tissue (proteins)** within the sarcomere:
  - Extends from the Z-disc to the M-line.
  - Elastic in PEVK region
  - Amino acids: proline, glutamate, valine, and lysine
- **Connective tissue related to fatigue?**
  - Weight bearing vs. non-weight bearing
  - "Hitting the wall"

Within the sarcoplasm
- **Sarcoplasmic reticulum**
- **Transverse tubules**
- **Terminal cisternae**
- **Mitochondria**

Neuromuscular Junction
- **Motor end plate**: pocket formed around motor neuron by sarcolemma
- **Neuromuscular cleft**: short gap
- **Ach** is released from the motor neuron:
  - Causes an end-plate potential (EPP)
  - Depolarization of muscle fiber

Muscle Structure
Key components in the muscle cell

- **Mitochondria**
  - Within muscle cell (in cytoplasm)
  - Main function: Location of oxidative conversion of foodstuffs into usable cellular energy
  - Limiting factor in running endurance performance?
- **Fat Droplets**
  - Fats generally stored in fat cells
  - ...but, can be stored in muscle cell as triglyceride molecules
  - Source of energy
  - Lipolysis; enzyme: lipase
Muscle Structure

Key components in the muscle cell

- **Glycogen**
  - Polysaccharide (i.e., animal starch)
  - Lots of glucose molecules
  - Breakdown of glycogen to glucose
  - Formation of glycogen from noncarbohydrate sources
  - Formation of glycogen from carbohydrate sources
  - Glycogen stored in muscles and liver
  - Total glycogen storage is relatively small and can be depleted in a few hours of exercise

Muscle Structure: Fiber Type

- **Oxidative**
  - High content of myoglobin
  - Orbital transfer: solar to mitochondria and not as a glucose source in suicidal
  - Slow contraction time vs. Type II
    - but contraction time for some athletes may be comparable to Type II contraction times of non-athletes
  - Fatigue resistant

- **At least 5 subtypes (Ia, Ib, IIc, IIb, IIc)**
  - Type Ia
  - Oxidative-lycocytic
  - Intermediate — can be fatigue resistant
  - Type Ib
  - Glycotic
  - High force production
  - Short duration
  - Unclear origin
  - Capable of being developed to I or IIa?
  - More power than Ib

Muscle Fiber Types

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Fast Fibers</th>
<th>Slow fibers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type IIb</td>
<td>Type Ia</td>
</tr>
<tr>
<td>Number of mitochondria</td>
<td>Low</td>
<td>High/mod</td>
</tr>
<tr>
<td>Resistance to fatigue</td>
<td>Low</td>
<td>High/mod</td>
</tr>
<tr>
<td>Predominant energy system</td>
<td>Anaerobic</td>
<td>Combination</td>
</tr>
<tr>
<td>ATPase</td>
<td>Highest</td>
<td>High</td>
</tr>
<tr>
<td>$V_{max}$ (speed of shortening)</td>
<td>Highest</td>
<td>Intermediate</td>
</tr>
<tr>
<td>Efficiency</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Specific tension</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

Muscle Function

- **Primary functions related to human movement:**
  - Maintain Posture
  - Stabilize Joints
  - Generate Force
  - Other functions:
    - Protection
    - …

Muscle Contraction

- CNS signal
- …
- Upon reaching post-synaptic membrane threshold, signal is transmitted throughout muscle fibers of a motor unit (α motor neuron and all innervated muscle fibers).

Muscular Contraction

- The sliding filament model
  - Muscle shortening occurs due to the movement of the actin filament over the myosin filament
  - Reduction in the distance between Z-lines of the sarcomere
The Sliding Filament Model

Actin & Myosin Relationship

- Actin
  - Actin-binding site
  - Troponin with calcium binding site
  - Tropomyosin
- Myosin
  - Myosin head
  - Myosin tails

Energy for Muscle Contraction

- __________________ is required for muscle contraction
  - Myosin ATPase breaks down ATP as fiber contracts
- Sources of ATP
  - Phosphocreatine (PC)
  - Glycolysis
  - Oxidative phosphorylation

Muscle Function:
Role of Muscle

- _____________: (prime mover) functions to cause a movement
- _____________: functions to resist movement
- Stabilizer: functions to fixate an area so another movement can occur
- Synergist: assist another muscle
- Neutralizer: functions to prevent undesired movement

Muscle Function:
Muscle Action

- ________: No change in muscle length
- ________: Change in length (same external weight)
  - Concentric
    - muscle length shortens during contraction
  - Eccentric
    - muscle length increases during contraction
- ________: Angular speed is constant during contraction
  - Concentric
  - Eccentric
Muscle Performance

• How well muscle functions are carried out.
  – i.e., ability to generate force
• Factors that influence muscle performance:
  – Angle of attachment and pennation
  – Length-tension relationship
  – Force-velocity relationship
  – Fatigue

Muscle Performance: Angle of Attachment and Pennation

Muscle Performance: Length-Tension Relationship of Muscle Contraction

Muscle Performance: Force – Velocity Relationship

Muscle Performance

Fiber Type Composition
Sprinters vs. Endurance Athletes

<table>
<thead>
<tr>
<th>Type of Athlete</th>
<th>Type I Muscle Fibers (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprinters</td>
<td>26</td>
</tr>
<tr>
<td>Sprinters and Jumpers</td>
<td>37-39</td>
</tr>
<tr>
<td>Weight lifters</td>
<td>44-49</td>
</tr>
<tr>
<td>Cyclists and swimmers</td>
<td>50</td>
</tr>
<tr>
<td>Middle-distance runners</td>
<td>45-52</td>
</tr>
<tr>
<td>Elite half-marathon runners</td>
<td>54</td>
</tr>
<tr>
<td>Canoeist</td>
<td>60</td>
</tr>
<tr>
<td>Elite rowers</td>
<td>60-90</td>
</tr>
<tr>
<td>Elite distance runners</td>
<td>79-88</td>
</tr>
<tr>
<td>Cross-country skiers</td>
<td>72-79</td>
</tr>
</tbody>
</table>
Fiber Type Composition
Sprinters vs. Endurance Athletes

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Sprinter</th>
<th>Distance Runner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>Large (&gt;80kg)</td>
<td>Small (&lt;50kg)</td>
</tr>
<tr>
<td>Explosive Power</td>
<td>Very high</td>
<td>High</td>
</tr>
<tr>
<td>Aerobic capacity</td>
<td>Unimportant</td>
<td>Important</td>
</tr>
<tr>
<td>Fatigue resistance</td>
<td>Unimportant</td>
<td>Crucial</td>
</tr>
<tr>
<td>Muscularity</td>
<td>Essential</td>
<td>Disadvantage</td>
</tr>
<tr>
<td>Body type</td>
<td>Mesomorphic</td>
<td>Ectomorphic</td>
</tr>
<tr>
<td>Muscle fiber compositions</td>
<td>60% Type II</td>
<td>60% Type I</td>
</tr>
</tbody>
</table>

Training

• Purpose:
  – General tiredness (Taber's)
  – Reduction of force generating capability of muscle
• Develop muscle fiber types by training at different intensities.
• Muscle recruitment based upon:
  – related to intensity of exercise
    – Long slow distance: Type I
    – High intensity: Type II
  – Muscles are recruited based upon information received by the CNS
    – Cardiostat: control based upon O₂ supply to the heart or brain
    – Glycostat: control based upon blood glucose (protect brain?)
    – Thermostat: control based upon heat accumulation
• Protect the body from harming itself
  – Central fatigue
    – Neurotransmitters within brain change signals being sent to muscles.
  – Is muscle recruitment influenced by a perception of how much more work can be done?

“Only the fast and strong die young”

• Endurance athletes tend to outlive sprinters.
  – Health benefits from endurance exercise?
  – Related to muscle fiber type?
    • Fiber type influences chosen level of physical activity?
    • People with more Type II muscle fibers may be more prone to developing hypertension, diabetes and obesity (Bassett, 1994).
    • People with more Type I fibers have greater levels of blood HDL-cholesterol (Tikkeanen et al., 1991).

Summary

• Muscle Structure
  – Gross to cell level
  – Muscle fiber type
• Muscle Function
  – Generate force
    • Sliding filament theory
• Muscle Performance
  – Length tension
  – Force velocity
  – Angle of attachment
  – Fatigue
  – Training