Muscle Structure and Contraction

Chapter 2

Muscle Classification

- As many as eight types
- Red (type I)
  - long term
  - slow contractions
- White (type IIa)
  - short term
  - fast contractions
- White (type IIb)
- No change from one type to another
  - change within fast types

Muscle Types

- Smooth
  - blood vessels
  - autonomic
- Striated
  - voluntary
  - skeletal
- Cardiac
  - network
  - rhythmic

Muscle Classification cont…

- Change in the nerve root supply will change the muscles twitch properties.
- No gender differences.
- No change in the relative % of each type with training.
- Your birth determines your activity?

The three types of human muscle tissue

- Smooth, nonstriated muscle is found in the walls of the hollow viscera and blood vessels.
- Skeletal, striated muscle is attached to the skeleton and provides the force for movement of the bony leverage system.
- Cardiac, striated muscle is found only in the heart.

Sliding Filament

- ATP is energy when split into ADP+P.
- Electrical impulse (action potential) travels down the nerve and into T-tubules.
- Depolarization occurs (sodium and potassium exchange). Local and millisecond time lapse.
- AP stimulates the release of calcium.
- Calcium binds to troponin.
- Actin and myosin then combine.

Sliding Filament cont…

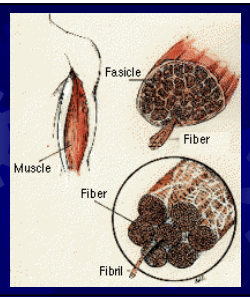
- Rigor of muscle upon death?
- Cross bridge cycle occurs.
- Nerve impulse stops.
- No calcium influx.
- Allowing troponin to attach and inhibit actin-myosin attachment.

Muscle Structure cont…

- Myofibrils contains protein myofilaments
- Actin and myosin
- Crossbridges protrude from myosin
- Arranged longitudinally in sarcomere
- From Z-line to Z-line
- Surrounded by sarcoplasmic reticulum

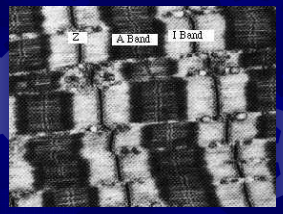
Neural Control

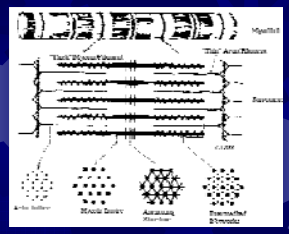
- Motor unit is one nerve and all fibers it innervates.
- 1:1 or 1:1,000.
- Large and small, fast and slow.
- Fibers may lie scattered throughout the muscle and not all together.
- Fiber diameter is related to work performed (hypertrophy?).
- When one fiber is activated all fibers are activated.



Muscle Structure

- Muscle fibers are long
- Diameter of a hair
- Grouped in bundles (fasciculi)
- Neuromuscular junction
- Sarcoplasm contains fibers
- Hundreds to thousands of myofibrils

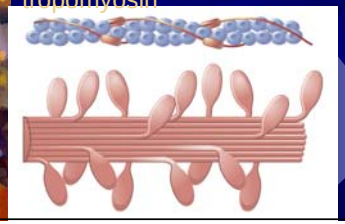




Resting Phase

- Little calcium in the myofibril
- Calcium stored in sarcoplasmic reticulum
- Very few crossbridges attached
- No tension in muscle

Contractile proteins actin, myosin, troponin, and tropomyosin



Excitation-Coupling Phase

- Calcium influx
- Calcium binds with troponin
- Troponin is on actin filaments
- Tropomyosin shifts
- Myosin crossbridge attaches to actin

Sliding Filament Theory

- Actin slides forward on myosin filaments
- Shortening the sarcomere
- Many must shorten for movement
- Rapid repeated contractions take place

Contraction Phase

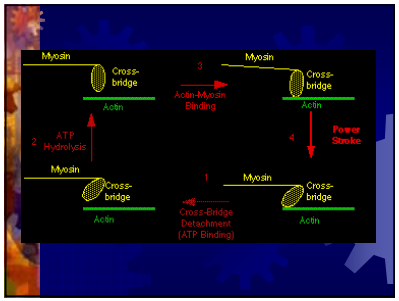
- Energy from hydrolysis of ATP
- Catalyzed by ATPase
- Another ATP to detach crossbridge
- Thus contraction continues
- Exhaustion of ATP, ATPase and calcium

Recharge Phase

- Muscle shortening
- Crossbridges work in cycle
- Relax when AP stops
- Calcium returns to sarcoplasmic reticulum (ATP for pump)

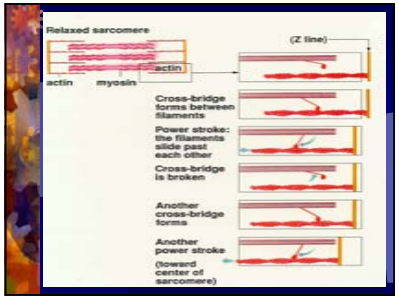
Types of Muscle Action

- Concentric – shortening
- Eccentric – lengthening (20% greater than concentric with less energy)
- Isometric – no change in length



Force Production

- Number of crossbridges dictates force
- Amount of calcium regulates crossbridge cycle
- Increased frequency of AP
- Number of active motor units
- Increased force
  - Frequency of stimulation
  - More motor units



Cross Sectional Area (CSA)

- Maximum force is related to CSA
- Larger CSA equals larger force
- Sarcomeres must be parallel
- More potential crossbridges
- Thicker muscles apply force

Velocity of Shortening

- Sarcomeres in series increase velocity
- Sarcomeres shorten simultaneously
- Longer muscles produce velocity
- Force production is inversely related to velocity
- Fewer crossbridges in contact
- Pennation angle affects force and velocity

DOMS

- Occurs 24-72 hours post exercise
- Muscle damage leads to inflammation
- Increase in muscle fluid
- Reduces strength
- Reduces oxidative process

Length-Tension Relationship

- Potential crossbridges depends on muscle length
- Percentage of contraction
- Long or short reduces force
- Resting length is optimal

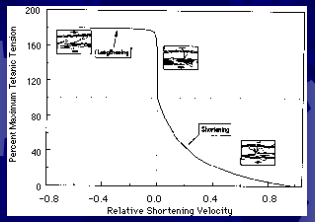
Older Muscle

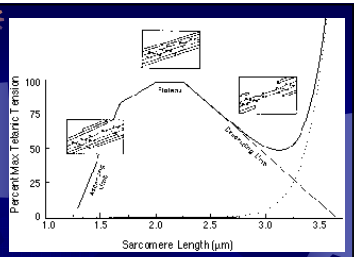
- Sarcopenia is loss of muscle mass
- Older adults especially
- Pronounced in lower limb extensors
- Predominately type II fibers
- Inactivity related

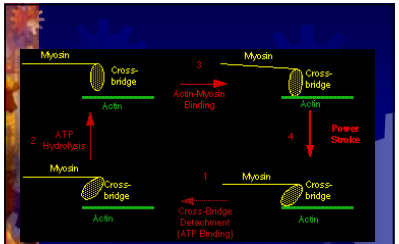
Stretch-Shortening Cycle

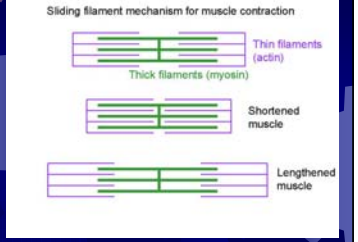
- Pre stretch of muscle
- Concentric preceded by eccentric
- Force is increased
- Stretch reflex potentiation
- Elastic energy

Concentric and eccentric.

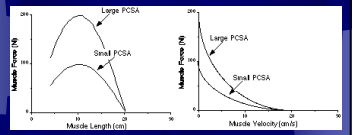


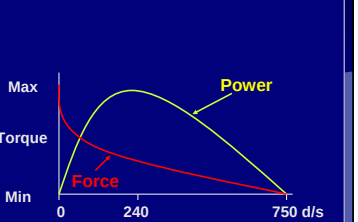




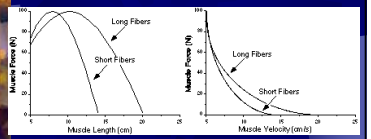


Muscle force is proportional to physiologic cross-sectional area (PCSA). (mass?)

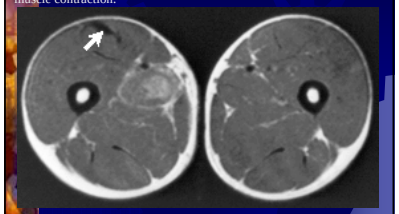




Muscle velocity is proportional to muscle fiber length.



The first measurable effect is an increase in the neural drive stimulating muscle contraction.



Hypertrophy results primarily from the growth of each muscle cell, rather than an increase in the number of cells.

The three primary fiber types in human skeletal muscle

- Slow twitch oxidative (SO)
- Fast twitch oxidative glycolytic (FOG)
- Fast twitch glycolytic (FG)

Muscle fiber types are classified by

- Anatomical appearance: red versus white
- Muscle function: fast-slow or fatigable versus fatigue resistant
- Biochemical properties: such as high or low aerobic capacity
- Histochemical properties: such as enzyme profile

Characteristics of muscle fiber types

A. Nomenclature			
1. Older systems	Red slow twitch (ST)	White fast twitch (FT)	
2. Dubowitz and Brooke (2)	Type I	Type IIa	Type IIb
3. Peter et al. (7)	Slow, oxidative (SO)	Fast, oxidative, glycolytic (FOG)	Fast, glycolytic (FG)
B. Characteristics			
1. Speed of contraction	Slow	Fast	Fast
2. Strength of contraction	Low	High	High
3. Fatigability	Fatigue resistant	Fatigable	Most fatigable
4. Aerobic capacity	High	Medium	Low
5. Anaerobic capacity	Low	Medium	High
6. Size	Small	Large	Large
7. Capillary density	High	High	Low

Characteristics of the structure of skeletal muscle

- The muscle is made up of long, cylindrical fibers.
- Each fiber is a large cell with up to several hundred nuclei.
- Each cell is structurally independent of its neighboring fiber or cell.
- The muscle has cross-striations of alternating light and dark bands.

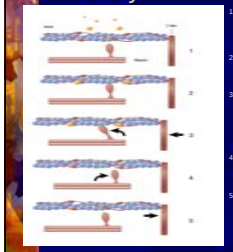
Structure of the myofibril

- Sarcomere
  - functional unit
  - composed of two types of parallel myofilaments
    - Myosin
    - Actin
- Z-line
  - membrane that separates sarcomeres
- A band
  - dark band seen as part of striation
- H zone
  - amount by which the two ends of the thin filaments fail to meet
- I band
  - area between the ends of the myosin
  - light band in the striation

Significance of fiber-type composition for athletes

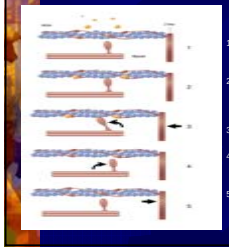
- High percentage of SO fibers—candidate for distance running or other endurance sports
- High percentage of FT fibers—candidate for power or sprint events
- Percentage is genetically determined

Theory 2



1. Myosin cross-bridge stores energy from breakdown of ATP by myosin ATPase Actin-myosin binding releases stored energy
2. Causes myosin cross-bridge to swivel ADP and Pi are released from the myosin cross-bridge
3. Fresh ATP molecule binds to myosin cross-bridge Actin-myosin binding released ATP is broken down and energy causes myosin cross-bridge to stand back up (re-energized)
4. Fresh ATP molecule is broken down Energy reenergizes myosin cross-bridge
5. Process repeats

Series of events that lead to muscle contraction in the sliding filament model



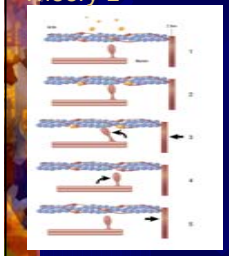
Contraction

1. Neural stimulation causes the sarcoplasmic reticulum to release calcium.
2. Calcium binds to troponin, which removes the inhibitory effect of tropomyosin and actin-myosin bind.
3. Myosin cross-bridges swivel, pulling the actin and z-lines.
4. Fresh ATP binds to the myosin cross-bridges, leading to cross-bridge recycling.
5. Neural stimulation ceases and relaxation occurs.

Comparing the two theories

- Both theories state that fresh ATP binds to the myosin cross-bridge to release it from actin during cross-bridge recycling.
- Theory 2 states that after the myosin-actin binding is released, the fresh ATP molecule is broken down and the energy released is used to reenergize the myosin cross-bridge.
- According to Theory 1, energy is not needed to cause the myosin cross-bridge to stand back up.

Theory 1



1. Actin-myosin bind
   Activates myosin ATPase
   Breakdown of ATP molecule liberates energy
2. Energy causes myosin cross-bridge to swivel to center of sarcomere Myosin is bound to actin, which is bound to Z-lines
   Z-lines pulled closer together
   Sarcomere shortened
3. Fresh ATP molecule binds to myosin cross-bridge
   Actin-myosin binding released
   Myosin cross-bridge stands back up
4. Actin-myosin rebinds at new site
   Activates myosin ATPase
   Breakdown of ATP molecule liberates energy
5. And process repeats

Next Class

- Collect velocity spectrum data
- Make Excel graphs of force/velocity and power/velocity curves