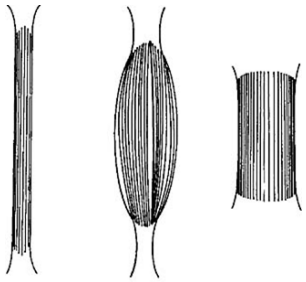
Muscle Mechanics: What contributes to muscular force production?

- Cross Sectional Area/Fiber Arrangement
- Force—Length Relationship
- Force—Velocity Relationship, Fiber Type
- Power—Velocity Relationship, Fiber Type
- Firing Rate
- Biomechanics of Muscular Strength

Muscle Fiber Architecture

- Fiber arrangement, within a muscle, influences the function of that muscle
- Two basic architectures:
  - Longitudinal or parallel fiber arrangement
  - Angled or pennate fiber arrangement

Fiber Orientation: Parallel



Parallel fiber arrangements

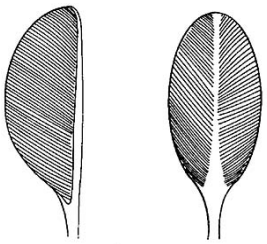
Fibers are parallel to the long axis of muscle

Muscle shortening length equals fiber shortening length, and muscle force equals fiber force

Favor large ROM and high speeds of movement

e.g., sartorius, biceps brachii, and rectus abdominus

Fiber Orientation: Pennate



Pennate fiber arrangements

Angled from long axis of muscle

Muscle shortening length is less than fiber shortening length, & muscle force is less than fiber force

More fibers in a given volume result in more force

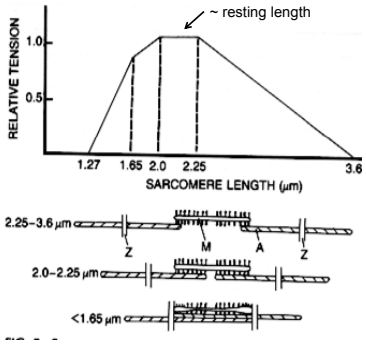
Results in lower range of motion, but greater force

e.g., tibialis posterior, rectus femoris, and deltoid

Hypertrophy or Hyperplasia?

- 9-23% increase over 3-5 months
- lifters had 76% larger biceps
- hyperplasia has been shown…in Japanese quail

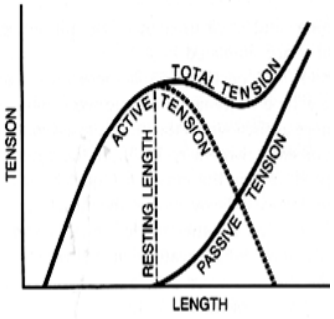
Muscles Mechanics: Force-Length



Active force, developed in the sarcomere, depends on overlap between actin and myosin filaments; this overlap depends on sarcomere length

Besides actin and myosin filaments, what else is capable of producing force in the muscle?

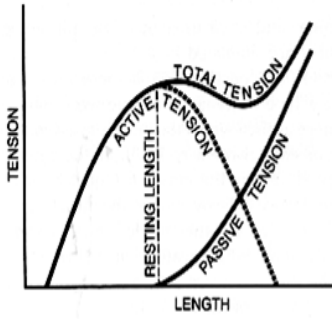
Muscles Mechanics: Force-Length



Total force developed by a muscle is the sum of active force, produced by cross-bridges, and passive force

What do you suppose creates this passive force?

Muscles Mechanics: Force-Length

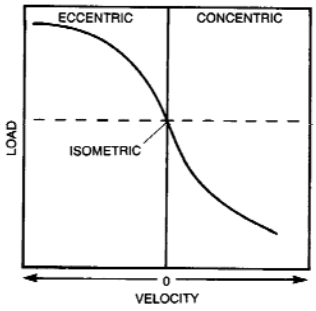


Peak force is reached at resting, or slightly longer than resting length

Many muscles reach peak force near the middle of total joint range of motion

Yet, there are some caveats to remember regarding this relationship…

Muscles Mechanics: Force-Velocity

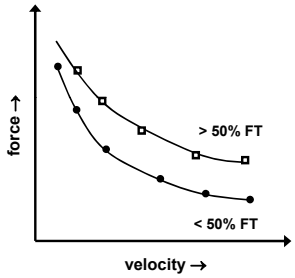


In addition to fiber length, peak force generating capabilities also depend upon how fast muscle length is changing

Resistance training increases the isometric load level

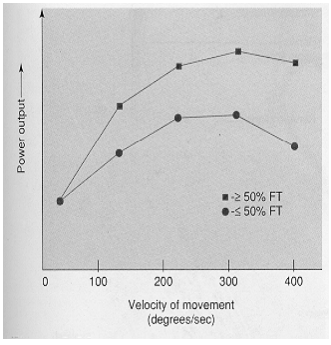
What does this imply concerning eccentric training? Pros and cons?

Muscles Mechanics: Force-Velocity and Fiber Type



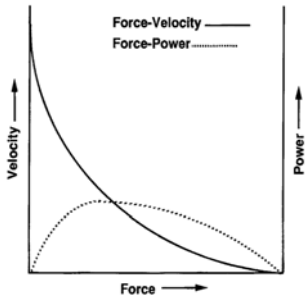
At a given speed of shortening, a muscle with more fast-twitch fibers can produce greater force than a muscle with more slow-twitch fibers

Muscles Mechanics: Power-Velocity



At a given speed of shortening, a muscle with more fast-twitch fibers can produce more power than a muscle with more slow-twitch fibers

Muscles Mechanics: Power-Velocity



Power = Force × Velocity

Maximum power is reached at about 33% of peak force and shortening velocity

According to this figure, how should one train for power?

Firing Rate

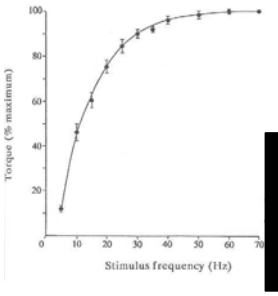


Figure 11.16 Force-frequency curve for human plantarflexor muscles. As the stimulus frequency to the tibial nerve is raised, the force developed by the muscle (expressed here as torque) becomes larger. However, beyond a certain optimal frequency, in this case 60 Hz, no further increase in force can be generated. Reprinted from Salo, Quiolan, Marsh, McComas, and Bilinger (1982).

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Biomechanics of Muscle Strength

How does all of this relate to strength?
What does it mean to be "strong"?

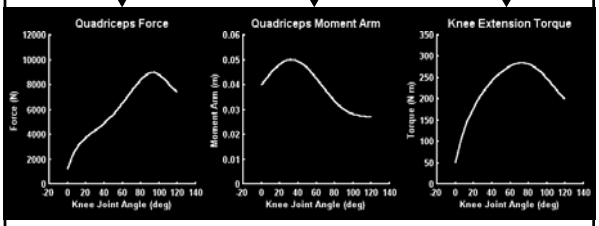
- **The ability to develop large joint torque!**
- **What does joint torque depends on?**

Muscle force and muscle moment arm ($d_\perp$, perpendicular distance, or r)

Both muscle force and moment arm vary with joint angle

Biomechanics of Strength: Knee Extension Torque

Muscle Force **Moment Arm** **Joint Torque**



Tendon and Ligament Mechanics

Considering their function, what would you suppose concerning the mechanical characteristics of tendon and ligament?

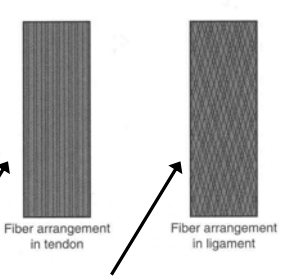
- **Composition…**
- **Mechanical properties: stress, strain, stiffness, strength…**
- **Viscoelastic?**
- **Anisotropic?**

Composition of Tendon and Ligament

- **Tendon and ligament consist of:**
  - **70% water**
  - **25% collagen**
  - **5% ground substance and elastin**
- **Ligaments have slightly less elastin and are slightly less strong, when compared to tendons**

Composition

A major difference between tendon and ligament is found in the arrangement of collagen fibers

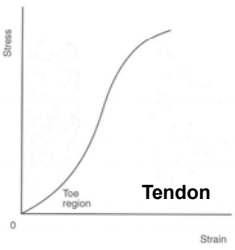


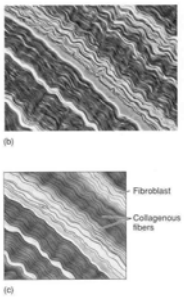
Very stiff for tensile, but not resistant to compression or shear

Better suited for non-axial loads, yet slightly less strong

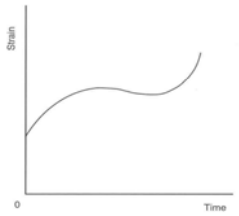
Tendon and Ligament

Collagen fibers are naturally "wavy" or "crimped"

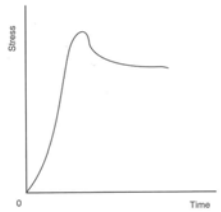




Creep and Stress Relaxation: Two Unusual Traits of Certain Biological Tissue



Stress is constant



Strain is constant