**Muscle and Tendon Mechanics Outline**

1. Muscle force and human strength
2. Some influences on skeletal muscle force production capability
3. A few factors that contribute to connective tissue force

**How does muscle force relate to human strength?**

What is required to be strong?

The ability to develop large joint torque

Again, what does joint torque depends on?

1. Muscle force, and
2. Corresponding perpendicular distance

Both of these factors are heavily influenced by joint angle

**Force, Perpendicular Distance, and Torque**

<table>
<thead>
<tr>
<th>Muscle Force</th>
<th>Perpendicular Distance</th>
<th>Muscle Torque</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quadriceps Force</td>
<td>Perpendicular Moment Arm</td>
<td>Knee Extension Torque</td>
</tr>
</tbody>
</table>

**What influences skeletal muscle force production?**

1. Cross Sectional Area (CSA)
2. Muscle Design
3. Fiber Length
4. Contraction Velocity
5. Fiber Type
6. Neuromuscular Factors

**CSA: Hypertrophy or Hyperplasia?**

- **Hypertrophy:**
  - 5% in 6 weeks; 15% in 8 weeks; 9-23% in 3-5 months

- **Hyperplasia:**
  - Antonio & Gonyea, 1993, and McCall et al., 1996

**Muscle Design**

Muscle design affects skeletal muscle force production

1. Two basic architectures
   - In-series
   - In-parallel

2. Pennation angle

Most muscles exhibit different combinations of these three characteristics
Fiber Architecture: In-series or parallel

In-series fibers:
excursion = fiber excursion × fiber number
force = fiber force

This arrangement results in greater ranges of motion and speeds, but less force

Parallel fibers:
excursion = fiber excursion
force = fiber force × fiber number

This arrangement facilitates high magnitude strength, but usually involves less motion

Architecture: Pennation Angle

Angle is relative to the long axis of muscle (θ > 0)
Muscle excursion is less than fiber excursion & muscle force is less than fiber force
However, more fibers in a given volume result in more force; results in less excursion, but greater force

Fiber Length

Active muscle force is influenced by the amount of myofilament (actin and myosin) overlap; this partly depends on fiber and sarcomere length

Fiber Length

Total tension equals the sum of active and passive tension
Peak tension is reached at resting length, or slightly longer than resting length (~120% of resting)
Many muscles reach peak force near the middle of joint range of motion

Contraction Velocity

Muscle force also depends on contraction velocity
Resistance training increases the isometric load level (i.e., raises the velocity × force curve)
What does this imply concerning eccentric training? Pros and cons?

Contraction Velocity & Power

Maximum power is reached at about 33% of peak force and shortening velocity
According to this figure, what is theoretically best when training for power?
**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;

![Graph](image1)

**Neuromuscular Factors:**

- **Firing Rate and Recruitment**
- **Tendon and Ligament Mechanics**
  - Tendons and ligaments consist of:
    - 70% water
    - 25% collagen
    - 5% ground substance and elastin
  - Ligaments have slightly less elastin and are slightly less strong than tendons

**Tendon and Ligament Mechanics**

- Small forces result in strain (~10%) that is elastic and rather spring-like
- Large forces can result in plastic strain (~20%)
- Stiffness depends upon CSA and collagen composition
- Tendons and ligaments are both viscoelastic and anisotropic
Stress Relaxation: An Unusual Traits of Most Connective Tissue

Strain is constant