The Limits of Human Strength

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The Limits of Human Performance
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What does it mean to be “strong”

- Nearly all of our joints move by rotating
- A torque is necessary to produce rotation
- Therefore, being strong means being able to generate large torques at your joints

- From physics, torque (T) equals force (F) times distance (d) ($d$ is also called the ‘moment arm’)
  \[ T = F \cdot d \]
- So, how do we relate this to human joints?

Human Joint Torque

- The dumbbell (load) creates a torque that tends to extend the elbow (CW)
- This is countered by the muscle, which creates a torque that tends to flex the elbow (CCW)

\[ \Sigma T = 0 \quad \Rightarrow \quad T_{\text{muscle}} - T_{\text{load}} = 0 \]
so, \( T_{\text{muscle}} = T_{\text{load}} \)
and, \( (F \cdot d)_{\text{muscle}} = (F \cdot d)_{\text{load}} \)
Note that \( d_{\text{load}} \) is >> than \( d_{\text{muscle}} \),
so \( F_{\text{muscle}} \) must be >> than \( F_{\text{load}} \)

To increase strength you need larger muscle moment arm, more muscle force, or both.
Muscle Moment Arm

- Moment arm is determined by the arrangements of your muscles, tendons, bones, and joints
- Muscle moment arm does change as you move your joint
- However, muscle moment arm does not change much, if at all, with training

Muscle Structure

- Muscle
- Fascicle
- Fiber (cell)
- Myofibril
- Sarcomere
- Myofilaments
  - Actin (thin filament)
  - Myosin (thick filament)

Muscle Force

- Force and motion are the result of cross-bridge formation between actin (thin) and myosin (thick) filaments
- Each crossbridge produces 0.000000000004 newtons of force, and can shorten the muscle by 0.000000011 meters
- Large muscles can produce >1000 newtons of force, and can shorten by several centimeters

Muscle Hypertrophy

- Muscle force is proportional to the amount of contractile protein found in cross-section
- Resistance exercise is one of several stimuli that cause muscles to increase in cross-sectional area
  - This process is known as hypertrophy
- Muscle hypertrophy is the result of genetic up-regulation of processes that lead to protein synthesis
Muscle Hypertrophy

- Inside the muscle fibers (cells)
  - Existing myofibrils gain additional contractile proteins
  - At a certain size, myofibrils split, allowing each to incorporate more contractile material
- As the myofibrils increase in size and number, the fibers get larger in cross-section
- However, the total number of muscle fibers remains nearly constant with training

Muscle Hypertrophy

- There appears to be a maximum size that muscle fibers can grow to
  - This ultimately sets a limit on the amount of hypertrophy that is possible
- Despite this limitation, incredible increases in muscle size and strength are indeed possible

The Neural Component

- To generate force, muscles must be activated by the nervous system
- Neural factors definitely influence muscle force
  - Changes in strength during the first few weeks of training are almost entirely neural in nature
- Neural adaptations that affect muscle force
  - Enhanced muscle recruitment
  - Increases neural firing rates
  - Improved neural coordination
  - Greater synchronization of activation

Up next ...

- Factors that determine and limit human endurance