Improving Muscular Strength and Endurance

Outline

- Introduction
- Structure of Skeletal Muscle
- How Skeletal Muscle Contracts
  - Motor Neurons
  - Actin and Myosin
- Types of Contractions
- Muscle Fiber Types
- Determinants of Muscular Strength
- Trainability of Muscle
- Muscular Strength and Aging

Skeletal Muscle

- Human body contains about 600 skeletal muscles
  - 40-50% of total body weight
- Functions of skeletal muscle
  - Force production for locomotion and breathing
  - Force production for postural support
  - Heat production during cold stress

Muscle Strength and Endurance

- Muscle Strength
  - Maximum force a muscle can generate
  - Often measured as one repetition maximum
- Muscle Endurance
  - Amount of time/number of repetitions that a muscle can maintain the same force
  - Often measured via one minute push up or sit up test (for examples)

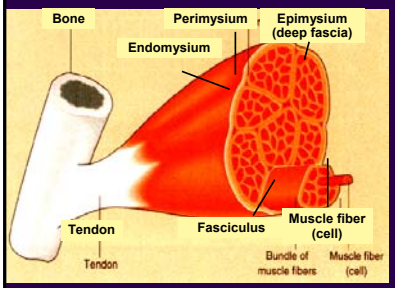
Benefits of Muscular Strength and Endurance

- Decreased incidence of chronic low-back pain
- Maintenance of strength with increasing age (rather than loss)
- Decreased losses in bone density
- Improved ability to do daily/household tasks
- Elevation in resting metabolic rate

Structure of Muscle

- Muscle, like all tissues, is made up of individual cells
- These cells are also called “fibers”
- The fibers are connected by a tough, semi-transparent tissue called fascia
- The fascia around the entire muscle is called the epi (outside/around) mysium (muscle)
- The epimysium at the ends of the muscle become the tendons that attach the muscle to bone

Skeletal muscle structure



- Endomysium: covers muscle cell
- Epimysium: covers entire muscle
- Tendon – connects muscle to bone

Muscle Contraction – Starts with Motor Neurons

Nervous System

Peripheral NS (as opposed to CNS)

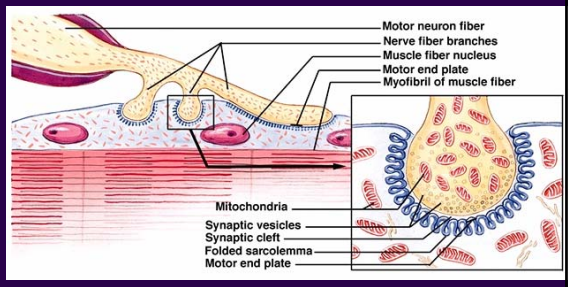
Motor Nerves

Autonomic Nerves	Somatic Nerves
Smooth muscle	Skeletal muscles
Cardiac muscle	Voluntary
Involuntary	

Motor Neuron Initiates Muscle Contraction

- Site where motor neuron meets the muscle cell there is a small gap called the synapse or neuromuscular cleft
- Acetylcholine, a neurotransmitter, is released from the motor neuron
  - Acetylcholine binds to a receptor on the muscle cell
  - This causes electrical changes in the muscle cell called an “action potential”
  - Action potentials lead to muscle contraction
  - Several poisons work by interrupting this nerve-muscle communication

Illustration of the Neuromuscular Junction



Motor Unit

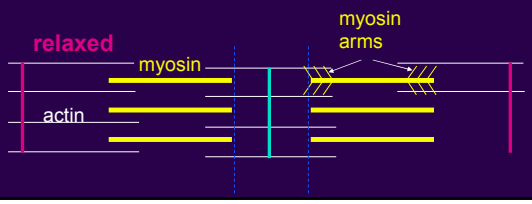
- Motor unit = one motor neuron and all the muscle cells it innervates
- Innervation ratio – number of muscle cells per motor neuron – variable from muscle to muscle
- Innervation ratio is low for fine motor control (e.g., hand muscles) and high for gross motor control (e.g., big leg muscles)

How Muscle Cells Contract

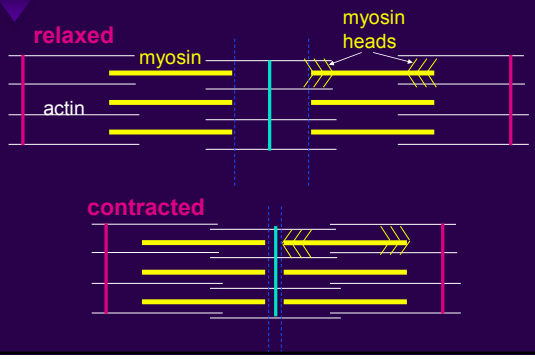
- Myofibrils, the contractile elements inside a fiber, consist primarily of two proteins: Actin and Myosin
- The myosin protein has multiple arms which attach on to actin molecules
- When an action potential (from the nerve) stimulates the muscle, the myosin arms pull on the actin, shortening the muscle cell length
- Calcium is required for this process
  - Lack of sufficient calcium can lead to paralysis (“milk fever” in cows, e.g.)

How Muscles Contract: The Sarcomere

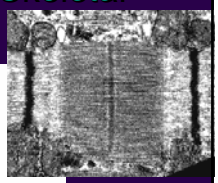
- The myosin and actin are organized into a series of units called sacromeres
- One sacromere is illustrated (myosin in yellow, actin in white)

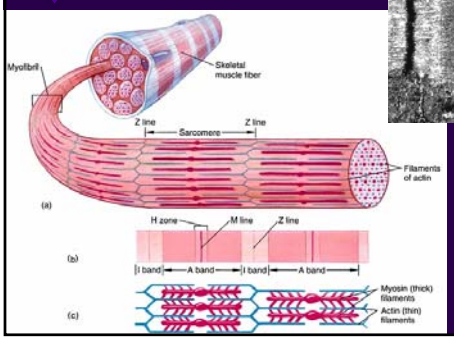


How Muscle Contracts: Sliding Filament Theory



Microstructure of Skeletal Muscle





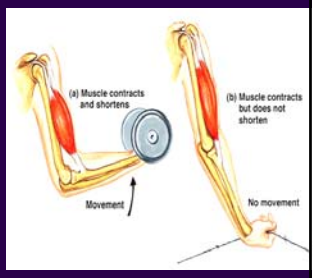
Types of Contractions

- Isotonic or Dynamic – involves movement
  - Concentric "miometric"
    - Muscle shortens
    - Lifting a barbell
  - Eccentric "pliometric" or "negative"
    - Muscle lengthens during contraction
    - Lowering a barbell
  - Isokinetic
    - Constant speed of contraction
    - Usually done on a machine

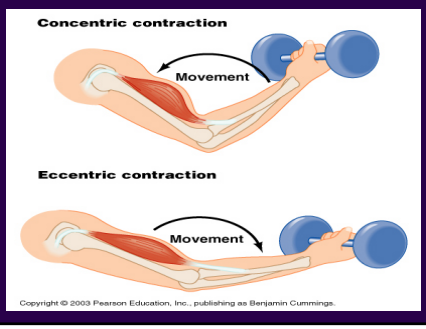
*Note, figure 5.4 may be confusing

Types of Contraction

- Isometric or Static – no movement
  - No change in muscle length
  - Pushing against a wall



Types of Contraction



Muscle Fiber Types

- Slow-Twitch “slow”
- Fast-Twitch glycolytic “fast”
- Fast-Twitch oxidative and glycolytic “intermediate”

Muscle Fiber Types: Slow

- Slow-Twitch – also called Type I
  - Red
  - High fatigue resistance
  - Lower force, slower speed
  - Example: soleus

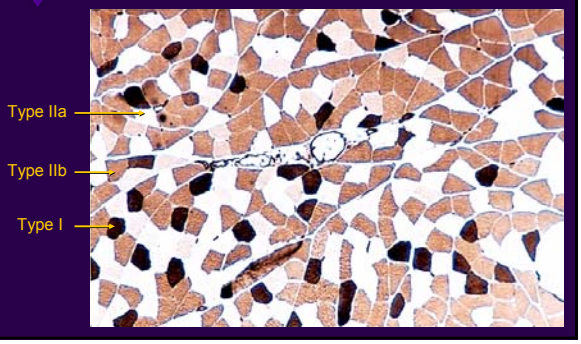
Muscle Fiber Types: Fast

- Fast-Twitch Glycolytic also called Type IIb
  - White
  - Fatigue quickly
  - Highest force, highest speed
- Fast-Twitch Oxidative and Glycolytic also called Type IIa
  - Red
  - Medium fatigue resistance
  - Medium force, medium speed

Muscle Fiber Types: Properties

Characteristic	Fast Fibers Type IIb	Type IIa	Slow Fibers Typel
Predominant energy system	anaerobic	combination	aerobic
Resistance to fatigue	low	high/moderate	high
Speed of shortening	highest	intermediate	low
Efficiency	low	moderate	high
Force (force/CSA)	high	intermediate	moderate

Histochemical Staining of Fiber Type



Fiber type differences between athletes

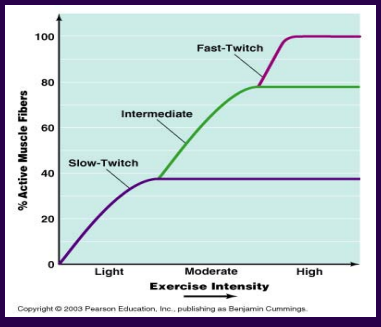
Sport	% Slow Fibers	% Fast Fibers
Distance runners	70-80	20-30
Weight lifters and Track sprinters	45-55	45-55
Nonathletes	47-53	47-53

- Performance = physiologic, biochemical, neurologic, and biomechanical properties

What Determines Muscular Strength?

- Muscle size
  - The greater the cross-sectional area of the muscle, the more force it can produce
  - Resistance training leads to increased muscle size
- Fiber Recruitment
  - The greater the number of recruited fibers, the greater the force (additive)
  - The greater the percentage of fast (esp. IIb) fibers, the greater the force
  - Fibers are generally recruited in order of efficiency: slow, then intermediate, then fast

Fiber Recruitment

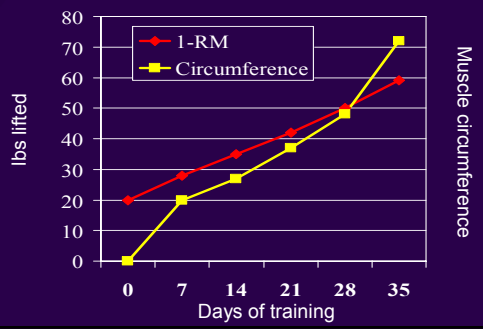


"Plasticity" of Skeletal Muscle

- Skeletal muscle demonstrates "plasticity", or in other words, muscle can be altered in response to removal of weight bearing forces (i.e., spaceflight, immobilization, bedrest, disuse) or to the addition of physical activity

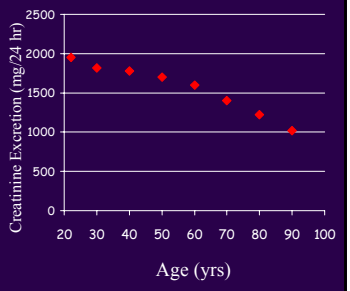
Adaptations may include changes in muscle fiber size and/or biochemical machinery (e.g., enzymes)

Adaptation to Strength Training – Increased Muscle Size and Strength

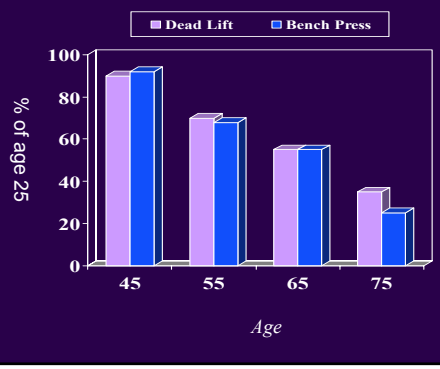


Loss of Muscle Mass with Age

- Loss of lean muscle mass attributed to:
  - Hormonal changes
  - Inactivity
- Loss of lean muscle mass may impair a person's ability to perform functional tasks



Changes in Strength With Aging



“Trainability” of older muscle

- Compared to younger individuals:
  - Older individuals can achieve the same relative (%) gains in strength and aerobic capacity with resistance or aerobic training