Chapter 6

Biomechanics of Skeletal Muscle

Behavioral Properties of the Musculotendinous Unit

1) **extensibility**: ability to be stretched or to increase in length

2) **elasticity**: ability to return to normal resting length following a stretch

3) **irritability:** ability to respond to a stimulus

4) **ability to develop tension:** the contractile component of muscle function

Behavioral Properties of the Musculotendinous Unit

3) **irritability:** ability to respond to a stimulus

4) **ability to develop tension:** the contractile component of muscle function

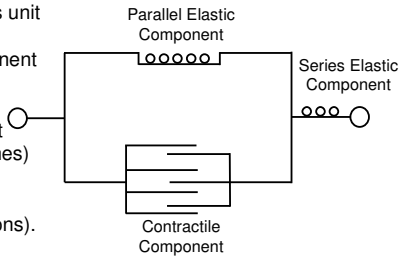
Components of Elasticity

• **parallel elastic component** – passive elasticity derived from muscle membranes

• **series elastic component** – passive elasticity derived from tendons when a tensed muscle is stretched

Musculotendinous Unit

From a mechanical perspective, the musculotendinous unit behaves as a contractile component (muscle fibers) in parallel with one elastic component (muscle membranes) and in series with another elastic component (tendons).



Stretch-Shortening Cycle

eccentric contraction (in which the muscle is actively stretched) followed immediately by concentric contraction

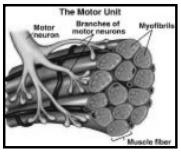
Muscle Fiber

single muscle cell surrounded by a membrane called the sarcolemma and containing specialized cytoplasm called sarcoplasm

Muscle Fibers

- some fibers run the entire length of a muscle; others are shorter
- skeletal muscle fibers grow in both length and diameter from birth through adulthood
- fiber diameter can be increased through resistance training

Motor Unit

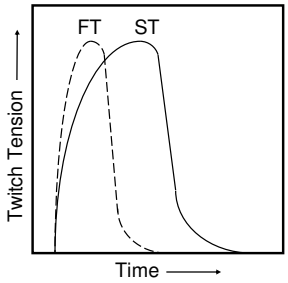


- **single motor neuron and all fibers it innervates**
- **considered the functional unit of the neuromuscular system**

Muscle Fiber Typing

Fast twitch (FT) fibers both reach peak tension and relax more quickly than slow twitch (ST) fibers.

Peak tension is typically greater for FT than for ST fibers.



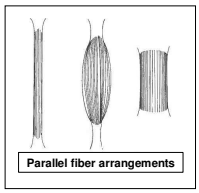
Skeletal Muscle Fiber Characteristics

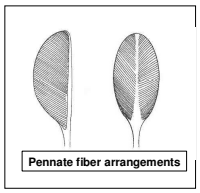
CHARACTERISTIC	Type I Slow-Twitch Oxidative (SO)	TYPE IIA Fast-Twitch Oxidative Glycolytic (FOG)	Type IIB Fast-Twitch Glycolytic (FG)
Contraction Speed	slow	fast	fast
Fatigue rate	slow	intermediate	fast
Diameter	small	intermediate	large
ATPase concentration	low	high	high
Mitochondrial concentration	high	high	low
Glycolytic enzyme concentration	low	intermediate	high

Structural Organization of Skeletal Muscle

- **parallel fiber arrangement**: fibers are roughly parallel to the longitudinal axis of the muscle
- **pennate fiber arrangement**: short fibers attach to one or more tendons within the muscle

Structural Organization of Skeletal Muscle





Motor Unit Recruitment

- slow twitch (ST) fibers are easier to activate than fast twitch (FT) fibers
- ST fibers are always recruited first
- increasing speed, force, or duration of movement involves progressive recruitment of MUs with higher and higher activation thresholds

Muscle Contraction Types

Occur during muscle activation

- **concentric:** involving shortening
- **eccentric:** involving lengthening
- **isometric:** involving no change

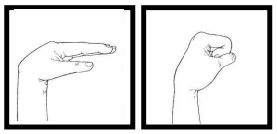
Muscle Roles

- **agonist:** acts to cause a movement
- **antagonist:** acts to slow or stop a movement
- **stabilizer:** acts to stabilize a body part against some other force
- **neutralizer:** acts to eliminate an unwanted action produced by an agonist

Biarticulate Disadvantages

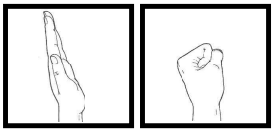
- **active insufficiency:** failure to produce force when slack
- **passive insufficiency:** restriction of joint range of motion when fully stretched

Active Insufficiency



failure to produce force when muscles are slack (decreased ability to form a fist with the wrist in flexion)

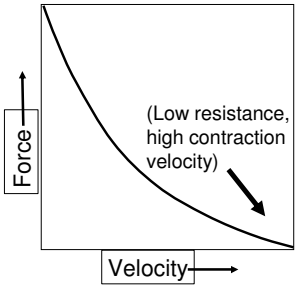
Passive Insufficiency



restriction of joint range of motion when muscles are fully stretched (decreased ROM for wrist extension with the fingers extended)

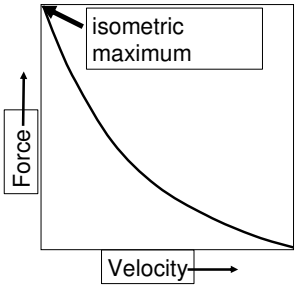
Force-Velocity Curve

When resistance (force) is negligible, muscle contracts with maximal velocity.



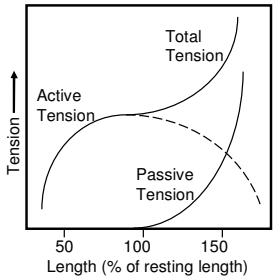
Force-Velocity Curve

As the load increases, concentric contraction velocity slows to zero at isometric maximum.

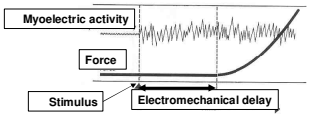


Length-Tension Curve

Tension present in a stretched muscle is the sum of the active tension provided by the muscle fibers and the passive tension provided by the tendons and membranes.



Electromechanical Delay

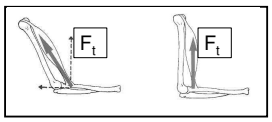


time between arrival of a neural stimulus and tension development by the muscle

Muscular Strength

the amount of torque a muscle group can generate at a joint

Muscular Strength



The component of muscle force that produces torque (F_t) at the joint is directed perpendicular to the attached bone.

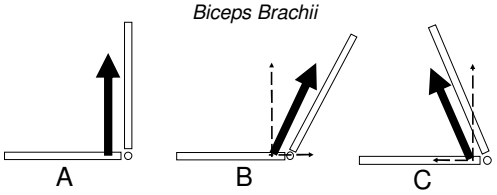
Factors Affecting Muscular Strength

tension-generating capability of the muscle tissue

- muscle cross-sectional area
- training state of muscle
- Moment Arm – distance between muscle attachment to bone and joint center
- Angle of muscle attachment to bone

Mechanical Advantage

Biceps Brachii



A) maximum when the elbow is at approximately 90º because 100% of muscle force is acting to rotate the radius.
B) Mechanical advantage decreases as the joint angle increases from 90º because more of the force is pulling the radius toward the elbow
C) Mecanical advantage decreases as the joint angle decreases from 90 º because more and more of the force is pulling the radius away from the elbow.

Muscular Power

- the product of muscular force and the velocity of muscle shortening
- the rate of torque production at a joint
- the product of net torque and angular velocity at a joint

Muscular Strength, Power and Endurance

What is muscular endurance?

- the ability of muscle to exert tension over a period of time
- the opposite of muscle fatigability

Warm-Up

the speeds of nerve and muscle functions increase

Force-Velocity Curve

Post Warm-up

- shifts to the right

- higher maximum isometric tension

- higher maximum velocity of shortening possible at a given load