

The Muscular System – Lecture Outline

1. Functions

- A. Support, Stabilization, and Protection
- B. Movement
- C. Body Temperature Regulation
- D. Contraction

2. Membrane potentials: resting and action

- A. Resting membrane potential
 - cell is at rest,
 - inside of cell more negative because more Na^+ and K^+ outside the cell,
 - cell is polarized (70 millivolt inside)
- B. Action Potential
 - cell will conduct electrical impulse,
 - only muscle and nerve cells do this
 - there are 2 stages:
 - 1. Depolarization
 - where Na^+ diffuses into the cell,
 - +30mV inside cell
 - 1. Repolarization
 - where K^+ diffuses out of the cell,
 - -70mV outside cell

3. Skeletal Muscle and Sarcomere

- A. Structure
 - muscle cells are called fibers,
 - muscle also contains connective tissue, blood vessels and nerve fibers
 - 1. Muscle fibers
 - elongate multinuclear cells,
 - cytoplasm is called sarcoplasm,
 - are striated,
 - striations are due to linear arrangement of myofibrils
 - large numbers of mitochondria and ER present,
 - red protein in sarcoplasm is called myoglobin,
 - myoglobin stores oxygen
- 2. Sarcolemma – is the muscle cell plasma membrane
 - a. Transverse or T tubules – invaginations of the cell membrane, increase surface area of membrane for absorption
- 3. Sarcoplasmic Reticulum – Ca^{++} -storing ER
 - a. Terminal Cisternae – Ca^{++} storage sites on T tubules
- 4. Myofibrils – protein fibers
 - a. Sarcomere – units that make up myofibrils, called myofilaments (actin – thin, and myosin - thick)
 - i. Dark band due or A band (myosin),
 - ii. Light band or I band (actin)

4. Muscle contraction

- due to sliding action of actin filaments,

- why and how does it take place?
- processes are:
- A. Nerve cell stimulation – electrical impulse travels along the axon
- B. Neuromuscular Junction – space between axon and sarcolemma,
 1. Axon releases neurotransmitter via exocytosis
 2. Neurotransmitter binds to receptors in sarcolemma
- C. Muscle Cell Stimulation
 1. Na^+ channels in sarcolemma open, Na^+ diffuses into cell, depolarization
 2. K^+ channels in sarcolemma open, K^+ diffuses out of cell, repolarization
 3. Action potential conducted down the muscle cell
 - a. Action potential in T tubules open Ca^{++} channels in Sarcoplasmic reticulum
 4. Ca^{++} diffuses out of sarcoplasmic reticulum into sarcoplasm
 - a. Ca^{++} triggers myosin attachment to actin
- D. Sliding Filament Theory – myosin pulls actin toward center of sarcomere
 1. Sarcomeres shorten, myofibrils shorten, muscle fiber shortens, hence bringing about muscle contraction and movement

5. Sources of Energy for Muscle Contraction ...

- A. ATP (Adenosine Triphosphate)– is the energy source in cells
 ATP ----- ADP + energy
 ADP + phosphate (from carbohydrates, protein, fat) ----- ATP
 1. Cellular respiration: glucose + ADP ----- ATP
 - a. Anaerobic Fermentation or glycolysis –
 - i. no oxygen required
 - ii. small amounts of ATP produced
 - b. Aerobic Respiration – glucose + fat + protein -----
 - CO_2 + H_2O
 - i. Oxygen required
 - ii. Large amounts of ATP produced
- B. Adaptations of muscle tissue to produce ATP
 2. Creatine phosphate stores phosphate at rest
 - a. Phosphate + ADP ----- ATP
 3. Myoglobin stores oxygen at rest
 - a. Oxygen quickly available for cellular respiration
- C. Oxygen Debt – difference between rate of oxygen production and consumption
 1. Oxygen consumed quickly by aerobic respiration
 2. Myoglobin depleted of oxygen
 3. Demand for oxygen exceeds supply
 4. Aerobic respiration stops due to lack of oxygen
 5. Anaerobic fermentation produces ATP and lactic acid
- D. Muscle Fatigue – occurs due to shortage of ATP
 1. Creatine phosphate and all ATP has been used up

2. No ATP to maintain contacts between actin and myosin
3. Muscle cell relaxes – called muscle fatigue
4. If no energy is available to pump Ca^{++} out of sarcoplasm, muscle cell stays contracted (cramping) during fatigue.

6. Movements of major superficial muscles

Names: based on body region, shape, size, direction of fibers, number of origins, locations of origins and insertions, and functions.

- A. Muscle Attachment Sites - muscles are attached to bones via tendons, muscle contraction pulls tendons, muscles never push but pull.
 1. Origin – attachment to a stationary body part
 2. Insertion – attachment to a moveable body part
- B. Coordination of muscle(s) to produce movement
 1. Agonists – prime mover, e.g., biceps brachii muscle flexes the forearm
 2. Antagonists – oppose the action of the agonist, e.g., triceps brachii extends the forearm
 3. Synergists – assists the prime mover
 4. Fixators – keep the origin stationary
- C. Muscles of the Face and Neck
 1. Frontalis – covers the head, contraction raises the eyebrows and wrinkles the forehead
 2. Orbicularis oculi – around each eye, contraction causes squinting or blinking
 3. Zygomaticus – from cheek to mouth corners, contraction brings about smiling
 4. Orbicularis oris – around the mouth, allows pursing and protruding the mouth
 5. Masseter – originating from the posterior zygomatic bone and inserting on the lateral mandible, elevates the mandible when talking, biting, chewing
 6. Temporalis – originating from the lateral skull and inserting on the lateral mandible, keeps the mouth closed
 7. Sternocleidomastoid – originating from the sternum and clavicle and inserting on the mastoid process of the temporal bone behind the ear, flexes, rotates or moves the head laterally.
- D. Muscles of the Trunk
 1. Trapezius – originating from the spinous processes of the posterior vertebrae and inserting on the spines of the scapula and the occipital bone of the skull, adducts, rotates and elevates the scapula and extends the head.
 2. Latissimus dorsi - originating from the spinous processes of the lumbar vertebrae and inserting into the shoulder joint, extends and adducts the arm
 3. Gluteus maximus – extends the thigh, used when running and climbing
 4. Gluteus medius – adducts and rotates the thigh, used when walking, site for intramuscular injection

5. Pectoralis major – originating from the sternum and inserting on the proximal humerus, flexes and adducts the arm; used in climbing, throwing, pushing, etc.
6. Rectus abdominus – multiple origins and insertions from the inferior rib cage down to the pubis; flexes and rotates the trunk (sit-ups), stabilizes the pelvis during walking, and increases the intra-abdominal pressure.
7. External oblique – found on the abdomen, its contraction sucks the gut in.

E. Muscles of the Upper Limb

1. Deltoid – thick muscle of the shoulder, abducts & rotates the upper arm.
2. Biceps brachii – two-headed muscle on the anterior forearm, flexes and rotates the forearm.
3. Triceps brachii – three-headed muscle on the forearm, extends the forearm at the elbow joint
4. Extensors of forearm – located on the posterior forearm, these muscles extend, abduct, and adduct the wrist and fingers.
5. Flexors of forearm – located in the anterior forearm, these muscles flex, abduct, and adduct the wrist and fingers.

F. Muscles of the Lower Limb

1. Sartorius – originating from the iliac crest and inserting in the medial knee, this muscle flexes and laterally rotates the thigh and crosses the legs.
2. Adductors (3) – three muscles originating from the medial pelvis and inserting on the medial knee, these muscles adduct and rotate the thigh and leg.
 - a. Adductor longus – anterior, medial
 - b. Adductor magnus – posterior, medial
 - c. Gracilis – middle thigh
3. Quadriceps Femoris (4) – originating on the anterior pelvis and femur and inserting on the proximal, anterior tibia, contraction of these muscles extends the lower leg at the knee; located on the anterior thigh.
 - a. Vastus lateralis – lateral, IM injection site
 - b. Vastus medialis – most medial
 - c. Rectus femoris – between V. lateralis and V. medialis
 - d. Vastus intermedius – deep, below the rectus femoris
4. Hamstrings (3) – located on the posterior thigh; originate from the posterior pelvis and femur; insert on the proximal posterior tibia; flexes the lower leg at the knee.
 - a. Semitendinosus – middle
 - b. Semimembranosus – medial
 - c. Biceps femoris – lateral
5. Tensor Fasciae Latae – weak muscle of the leg; originates from the iliac crest and inserts on the lateral knee
6. Gastrocnemius – two-headed muscle on the posterior lower leg; originates from the back of the knee joint and inserts on the heel bone; contraction causes the toes to point down.
 - a. Calcaneal (Achilles) Tendon – largest tendon attaching the gastrocnemius with the heel bone

7. Tibialis anterior – located on the anterior tibia; originates in the tibia, inserts on the top of the foot; contraction causes the toes to point up.