Tarrant County College District Massage Therapy Program
Kinesiology: Week 4, use with PPT -- Muscles and Motion ch. 14
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The Force of Muscle Contraction: Review Questions

Questions for Review of content of this lecture:

1. How can a muscle have a **partial contraction**?
2. What is the **Henneman size principle**?
3. Name two types of **longitudinal muscle fiber** architecture and three types of **pennate muscle fiber** architecture
4. What is a **lever**? What is a **lever arm**?
5. What is the definition of **leverage**?
6. What advantage does a muscle gain by having a greater leverage?
7. What disadvantage does a muscle have if it has greater leverage?
8. What is the **optimal angle of pull** for a muscle?
9. What is the definition of a **first class lever**?
10. What is the definition of a **second class lever**?
11. What is the definition of a **third class lever**?
12. What is the similarity between a second-class lever and a third class lever?
13. Name a muscle that acts as part of a third class lever system.
14. What is the importance of the **resistance force** to movement?
15. What is **Titin**?
16. Where would you find **Titin**?

Definitions:

1. Partial contraction
2. Henneman size principle
3. Longitudinal muscles
4. Pennate muscles
5. Level
6. Lever arm
7. Leverage
8. Optimal angle of pull
9. First class lever
10. Second class lever
11. Third class lever
12. Resistance force
13. Titin
14. Passive tension
15. Active tension

Lecture Materials for Muscles and Motion:

1. **Partial contraction of a muscle**
   a. The **all-or-none response law**: a muscle fiber contracts either all the way or not at all
      i. Whatever instruction is given to one fiber in a motor unit is given to all
      ii. Therefore: the all-or-none law applies to the motor unit
         1. If one fiber in a motor unit is contracting they are all contracting
         2. Stimulating a motor unit causes all fibers that are part of that unit to contract
   b. **Brain thinks in motor units**
      i. Motor units come in sizes (see later in these lecture notes)
         1. **Small – weaker**
         2. **Large – stronger**

ii. With need for weak contraction, smaller motor unit is recruited
iii. When the need is for stronger contraction, a larger unit (in addition to the smaller unit that is already contracting) is recruited
iv. **The contraction starts with the smaller unit and then incrementally adds increasingly larger motor units which causes a smooth transition to occur as a muscle begins its contraction and then increases the strength of its contraction**
v. This hierarchy of contraction recruitment is called the ***Henneman-size Principle***

c. Relationships:
i. Smaller motor units: innervated by smaller motor neurons and contain red, slow-twitch muscle fibers, which are more adapted toward creating joint stabilization
ii. Larger motor units are innervated by larger motor neurons and contain white, fast-twitch muscle fibers, which are more adapted toward creating joint movement
iii. Therefore, when joint action is ordered by the CNS, the smaller motor units that initially contract are meant to create stabilization of the joint before the larger motor units are recruited to create the larger motion at that joint

d. If every motor unit of a muscle contracts, the muscle will contract at 100% of its maximum strength **– full contraction**

e. If only some motor units are ordered to contract, then the muscle will have a **partial contraction**
i. The degree of this partial contraction is determined not only by the number of motor units recruited to contract, but also by the number of muscle fibers in these motor units
ii. When a person does strengthening exercises and builds up the muscles, the number of muscle fibers does not change; what changes is the size of each fiber
1. Exercise causes the number of sarcomeres and the number of contractile proteins (i.e. actin and myosin) to increase
2. The result: some fibers get larger and stronger than others
iii. The better determinate of strength for a muscle's contraction is the number of cross-bridges that are made between myosin and actin
iv. Another factor that must be considered, the orientation of the pull of the cross-bridges relative to the line of pull of the muscle itself.

2. **Definitions**

a. **Intrinsic strength:** defines as the strength that the muscle generates within itself (intrinsically). It is the result of the strength that the muscle generates internally because of the sliding filament mechanism (i.e. *active tension*) and the elastic recoil property of the tissues of the muscle (i.e. – *passive tension*). The intrinsic strength of a muscle is independent of the external surroundings.

b. **Extrinsic strength:** all the factors outside the muscle itself. These include such things as the leverage that the muscle has on its attachments as well as the angle of the muscle's pull relative to the joint where movement is occurring.

c. **NB:** (note well) Only when considering both intrinsic and extrinsic forces can the sum total of a muscle's effect on its attachments (i.e. its strength) be understood.

3. **Muscle Fiber Architecture:**
    a. Two general architectural types
        i. **Longitudinal**
        ii. **Pennate**
    b. **LONGITUDINAL MUSCLES:**
        i. Has fibers running longitudinally (i.e. – along the length of the muscles from attachment to attachment
        ii. Force of the contraction of these fibers is in the same direction as the length of the muscle.
    c. **TYPES OF LONGITUDINAL MUSCLES:**
        i. Fusiform (aka spindle)
        ii. Strap
        iii. Rectangular
        iv. Rhomboidal
        v. Triangular (aka fan shaped)
        vi. Other types also included:
            1. Sphincter muscles (circular): orbicularis oculi and oris
            2. Spiral muscles: latissimus dorsi
    d. **TYPES OF PENNATE MUSCLES:**
        i. Fibers are arranged like a feather-like manner
        ii. Fibers not arranged along the length of the muscle, rather, a central fibrous tendon runs along the length of the muscle. The fibers are arranged obliquely to that central tendon
        iii. **TYPES:**
            1. **Unipennate muscle:** central tendon within the muscle and fibers are oriented diagonally along one side of the tendon
                a. **EX:** vastus lateralis of the Quadriceps Femoris group
            2. **Bipennate muscle**: has a central tendon within the muscle, and the fibers are oriented diagonally off both sides of the tendon
                a. **EX**: rectus femoris of the Quadriceps Femoris group
            3. **Multipennate muscle:** has more than one central tendon with fibers oriented diagonally either to one and/or both sides. It has a combination of unipennate and bipennate arrangements.
                a. **EX:** deltoid

4. **LONGITUDINAL AND PENNATE MUSCLES COMPARED:**
    a. **Fibers:**
        i. **Longitudinal muscle: long fibers**
            1. Fewer fibers
            2. Along the length of the muscle

ii. **Pennate muscle: short fibers**
    1. More fibers
    2. At an oblique angle to the tendon
iii. However, upon comparison of same size pennate and longitudinal muscles
    1. Both contain the same mass of muscle tissue
    2. The same number of sarcomeres
    3. The same number of myosin-actin cross bridges
iv. **Shortening of fibers: a muscle fiber shortens to approximately ½ of its resting length**
    1. **Longitudinal muscles have longer fibers, shorten more than pennate muscles**
        a. Are ideally suited to create a large range of motion of a body part at a joint
        b. But they have less force than pennate
    2. **Pennate muscles have shorter fibers but have a greater number of them than longitudinal muscles**
        a. Their strength is concentrated over a shorter range of motion
        b. They have greater strength

5. ACTIVE TENSION VERSUS PASSIVE TENSION:

a. Muscles can generate two types of forces:
    i. Active force
        1. The pulling force that the muscle generates
        2. Aka tension
    ii. Passive force
b. **Active Tension**
    i. Generated by the sliding filament mechanism (i.e. contraction)
    ii. Called active because
        1. The muscle is generating this itself
        2. Expending ATP to produce a contraction via actions of the actin-myosin cross bridges
c. **Passive Tension**
    i. Primarily the result of the muscle fibers themselves
    ii. When muscles are stretched the elastic fibers will try to bounce back to their resting length; this creates a pulling force back toward the center
        1. **Muscle fascia: great tensile strength**, which means it is resistant to stretching so not involved
        2. Its primary purpose (tendon, aponeurosis) is to transmit force from muscle contraction to the bone attachment
        3. Stretching would negate primary function
    iii. **Elasticity of muscle tissue resides in the muscle fibers themselves. Specifically in the large Titin molecules**
        1. **TITIN_**
            a. Largest protein in the human body
            b. Contains approximately 27,000 amino acids

c. Forms the **cytoskeleton** (cellular skeleton) for the sarcomere
   - **i.** It connects the myosin filament to the Z-line
   - **ii.** For this reason **Titin** is sometimes known as **Connectin**
   - **iii.** There are six **titin** molecules that attach to each side of the myosin filament

iv. Titan is now proposed to be primarily responsible for the elasticity and therefore the passive tension of extended muscle/myofascial tissue.
   1. The springy end-feel of a stretched muscle that is sensed by the therapist might be caused by titin
   2. Sources have posited (stated as probable subject to proof) that titin may also be responsible for chronic muscle stiffness that is felt with activities
      a. The increased stiffness may result from increased connections (i.e. adhesions) between *titin and the myosin filament* or perhaps even between the titin and the actin filament

v. The total tension in a muscle is generated by its contractile actin and myosin filaments and its natural elasticity.
   1. Both pieces must be considered when determining the force of a muscle's contraction.

6. LEVERAGE OF A MUSCLE:

a. Both intrinsic and extrinsic factors affect the strength with which a muscle can move a body part.
   - i. **Leverage – major extrinsic factor**
     1. Affects the force that a muscle can generate when moving a body part
     2. Leverage is a term that describes the mechanical advantage that a force can have when moving an object
   - ii. In the body, any movement that occurs will always be the sum total of all the forces that act on that body part
   - iii. Forces can be divided into two types
     1. Internal forces – generated inside the body
        a. Muscles generate internal forces
     2. External forces – created externally
        a. Gravity is the most common external force
        b. Weight
        c. Actions of others
        d. Wind
        e. Waves
        f. Heavy clothing

b. **LEVERS:**
   - i. **LEVER:** rigid bar that can move
     1. The movement occurs at the **axis of motion**
        a. In the body this is a **joint**
     2. Movement happens because force acts on the lever

a. The distance from the axis of motion to the point of application of force on the lever is defined as the **lever arm.**
   i. Aka: **moment arm** or **effort arm**
   ii. The longer the lever arm, the less effort to move something
      1. Archimedes
   iii. **Mechanical advantage** describes the advantage of being able to move heavy objects with less effort
   iv. Longer lever arm makes it easier to move an object that might otherwise be too difficult to move
      1. The lever arm must travel a great distance to move the object a short distance
   v. Increased leverage simply spreads what would be a large effort into a smaller effort over a greater distance

b. The see saw: the further from the axis of motion that a person sits, the more force that person exerts on the seesaw due to increased leverage

c. A door knob is nearly always located as far from the hinges as possible. This increased leverage provides increased mechanical leverage for opening or closing the door

d. When a muscle attaches farther from a joint, it gains mechanical advantage or leverage because the lever arm is longer.

c. **LEVERAGE IN THE HUMAN BODY:**
   i. *BONES ARE LEVERS*
   ii. *MUSCLES CREATE THE FORCES THAT MOVE THESE LEVERS*
   iii. *AXIS OF MOTION IS LOCATED AT THE JOINT*
   iv. The mechanical advantage or leverage of a muscle increases as its attachment site on the bone is located farther from the joint
      1. The location of the attachment of a muscle, although not changing the muscles intrinsic strength, does change the force of movement that the muscle exerts on its attachment, that is – its strength.
   v. **LEVERAGE:** an example of an extrinsic factor that affects the force that a muscle exerts on its attachments

7. **LEVERAGE OF A MUSCLE:**
   a. **The angle of pull is a factor in evaluating its strength**
      i. Lever Arm is defined based on the application of force to move the lever as being perpendicular to the lever i.e.—the pull of the muscle on its attachment should be perpendicular to the bone on which it attaches
      ii. This is rarely ever true

b. **Angle of Pull:**
   i. **Effective strength**—ability to move a body part at a joint based on the direction of the motion that is to occur
      1. What percentage of the force goes into movement
      2. What is lost
   ii. **Optimal angle of pull:** is perpendicular to the axis of the bone
   iii. If it is an oblique angle only a percentage of the force will become movement
   iv. **RULE: the optimal angle of pull is the angle that most efficiently moves the bone at the joint crossed, and any obliquity in the angle of the muscle's pull will result in a decrease in efficiency of movement when the muscle contracts.**
      1. There is an advantage to obliquity: it makes the force spend a greater proportion on stabilization

c. **Joint stability**:
   i. The compression of force of the bone in toward the joint results from obliquity and increases joint stability
   ii. Inherent in the term optimal angle of pull is a bias toward joint movement and a bias against joint stabilization
   iii. **Joint stabilization** is very important toward protecting a joint against injury.
      1. The role of the muscle is both to move a bone at the joint and also to contribute to stability at the joint

d. **Lever arm definition refined:**
   i. A more accurate definition of a musculoskeletal lever arm is the measurement of the line that begins at the center of the joint and meets the line of pull of the muscle at the perpendicular angle.

8. **CLASSES OF LEVERS**
   a. Divided into three classes – the difference between them is the relative location of the application of force to cause movement (F) and the force of resistance to movement (R) relative to the axis of motion (A)
   b. **First Class Lever:** *has the force that causes motion and the force of resistance to motion on opposite sides of the axis of motion*
      i. EX: a seesaw or teeter-totter
      ii. EX: in the human body – the extensor musculature that attaches to the back of the head
   c. **Second Class Lever:** *has the force that causes motion and the force of resistance to motion on the same side of the axis of motion*
      i. The force that causes motion is farther from the axis than the force of resistance
      ii. They are inherently of greater leverage for strength of pulling force
      iii. EX: wheel barrow
      iv. EX: musculature of human body – the plantar-flexor musculature of the lower extremities that attaches to the calcaneus
   d. **Third Class Lever:** *the force that causes motion and the force of resistance to motion on the same side of the axis of motion*
      i. The force that causes motion is closer to the axis than the force of resistance

ii. They have less leverage for strength of pulling force
iii. EX: tweezers
iv. EX: in the human body musculature – the brachialis that attaches to the proximal end of the forearm from the brachium
1. It has limited leverage for strength of contraction
2. It has that this short muscle can move the forearm thru a large range of motion with very little contraction

9. LEVERAGE OF RESISTANCE FORCES:

a. The force of resistance to our muscle's force may have greater leverage than out muscle does.
i. When this occurs whether the need is movement or stability, our muscle can be said to be at a **mechanical disadvantage**
ii. This occurs with second-class levers, because second-class levers are defined as having the resistance force farther from the joint than the muscular attachment