UNITED STATES MARINE CORPS
FORCE FITNESS READINESS CENTER
THE BASIC SCHOOL
24191 GILBERT ROAD
QUANTICO, VIRGINIA 22134

STUDENT OUTLINE

BIOMECHANICS AND KINESIOLOGY I

FFIC1040

FORCE FITNESS INSTRUCTOR COURSE

M02MN1T

APPROVED BY: LtCol (Ret) Shusko, J. C. DATE: 20190328 INT:_____

LEARNING OBJECTIVES

a. TERMINAL LEARNING OBJECTIVES

(1) Given a unit to train, supervise injury prevention, and to increase a Marine and units readiness. (0919-TRNG-2004)

b. ENABLING LEARNING OBJECTIVES

(1) Without the aid of reference, identify bone tissue behavior under stress without error. (0919-TRNG-2004v)

(2) Without the aid of reference, identify joint structures without error. (0919-TRNG-2004w)

(3) Without the aid of reference, identify factors of cartilage wear and degeneration without error. (0919-TRNG-2004x)

(4) Without the aid of reference, describe elastic vs plastic regions of ligament/tendon behavior without error. (0919-TRNG-2004y)

(5) Without the aid of reference, identify the types of muscle contraction without error. (0919-TRNG-2004aa)

(6) Without the aid of reference, identify the roles of muscle during contraction without error. (0919-TRNG-2004ab)

(7) Without the aid of reference, identify muscle and force relationships without error. (0919-TRNG-2004ac)

(8) Without the aid of reference, identify muscle effects without error. (0919-TRNG-2004ad)

INTRODUCTION: It is imperative that Force Fitness Instructors understand the principles of anatomy, physiology, and mechanics as it relates to human movement. The Instructor's level of understanding of the biomechanics of the human body is important for the teaching, supervising, and revising of individual Marines and unit physical fitness plans.

1. FUNCTIONS OF HUMAN TISSUE.

a. Bone. Bones provide structure to the body and serve as attachment points for muscles.

(1) Composition and Structure. Bones are uniquely designed and may harden with training and exercise.

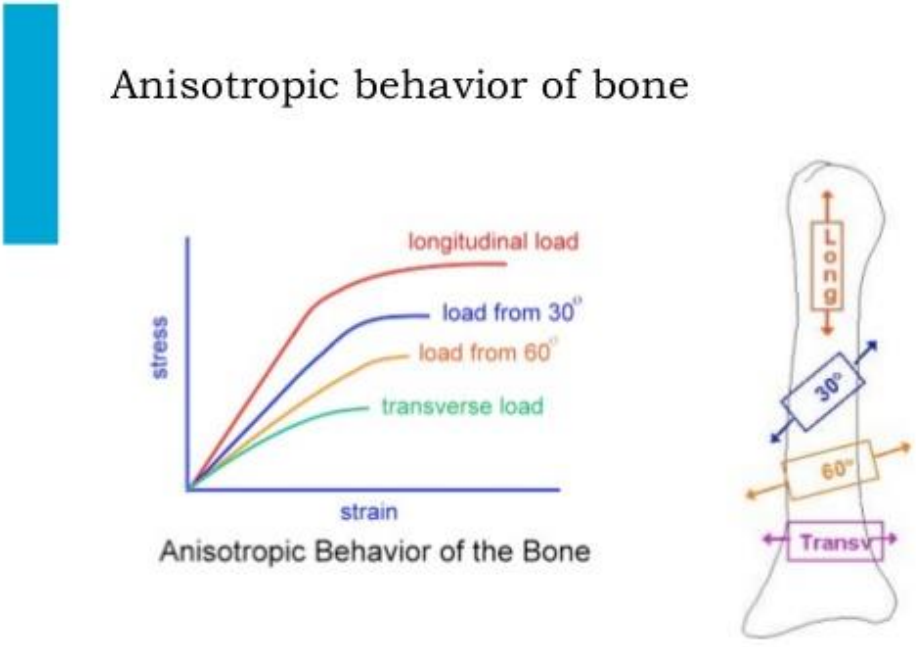
(a) Storage: Bone serves as reservoir for essential minerals in the body, especially calcium.

(b) Growth: Bones will grow longitudinally as long as end plates are open. End plates may close at age 18.

(c) Bones are able to accommodate limited deformation dependent on direction and magnitude of stresses.

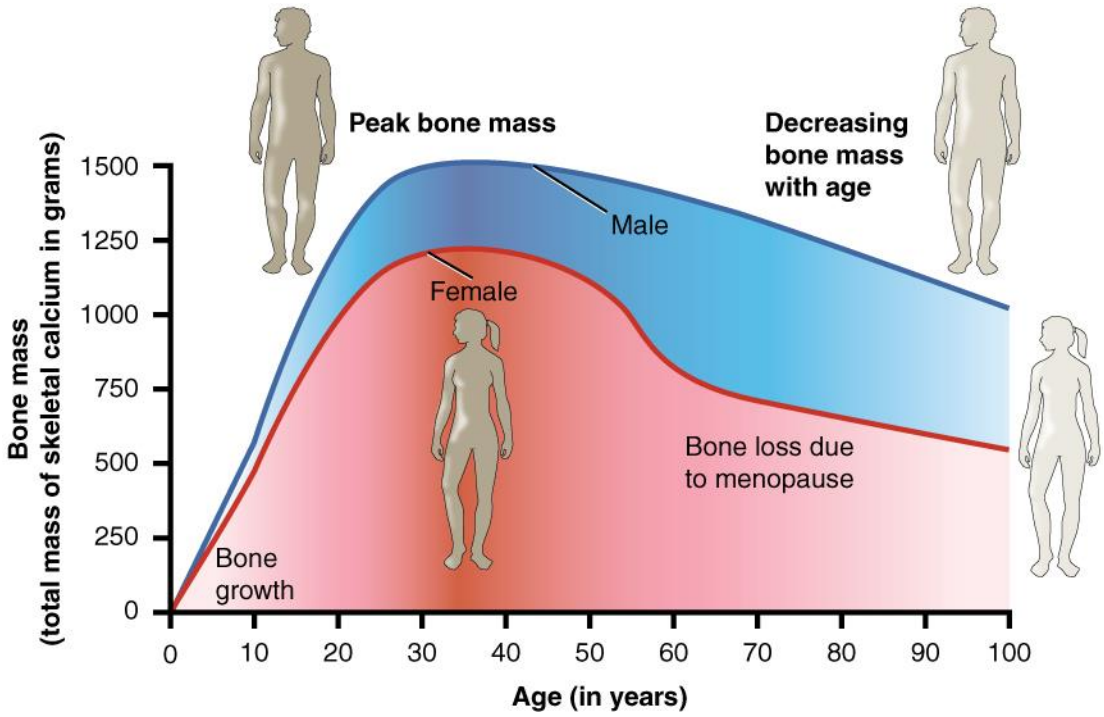
(d) 25% weight of bone is water

(2) Loading & Stress Behavior. Stress can occur in a variety of ways: tension, compression, sheer, bending, and torsion. Below is a graph depicting the "Load – Deformation curve." The bone is more resilient when force is applied in the longitudinal position and it's resistance to stress decreases as the stress approaches the transverse plane.



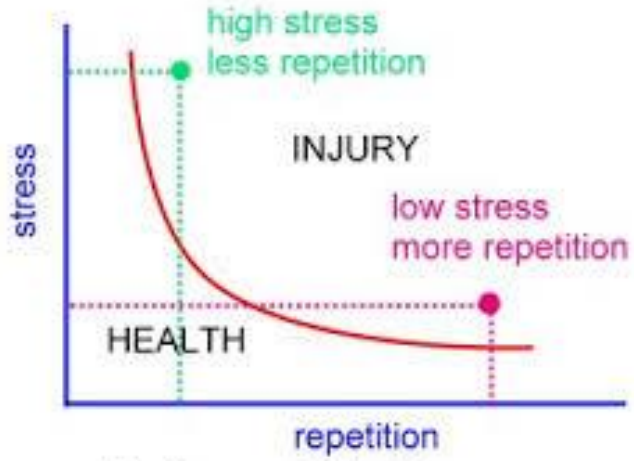
(3) Degenerative Changes in Bone Associated with Aging. Progressive loss of bone is normal with aging.

(a) Age, gender, and body mass. All three of these are factors in bone density.



(4) Muscle Activity on Stress Distribution on Bone. Contraction of the muscle alters the stress distributed in the bone. The muscle contraction decreases or eliminates stress partially or totally.

(5) Fatigue of Bone under Repetitive Loading. Bone can fracture by a single load that surpasses its ultimate strength or by repeated load application of a load of lower magnitude. As muscles fatigue, they are no longer able to absorb energy.



Fatigue of the Bone

b. Joints.

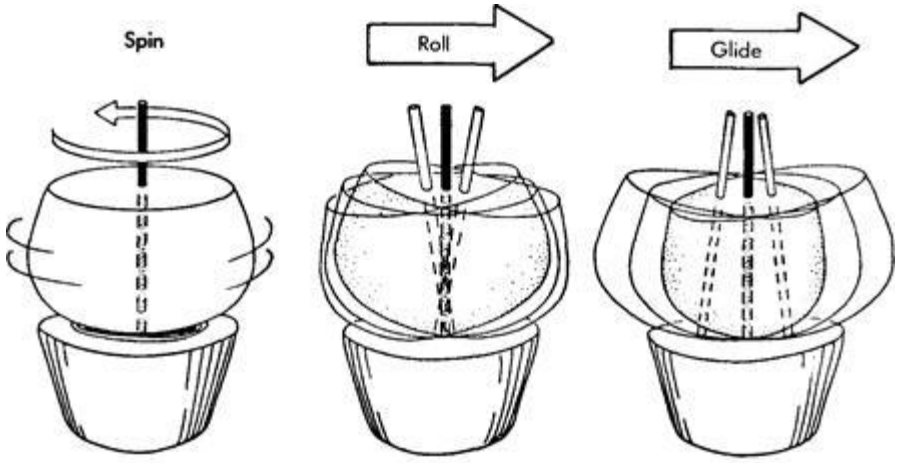
(1) Structure. Joints may be classified by structure or function. For the purposes of this class, we will focus on the structure of joints.

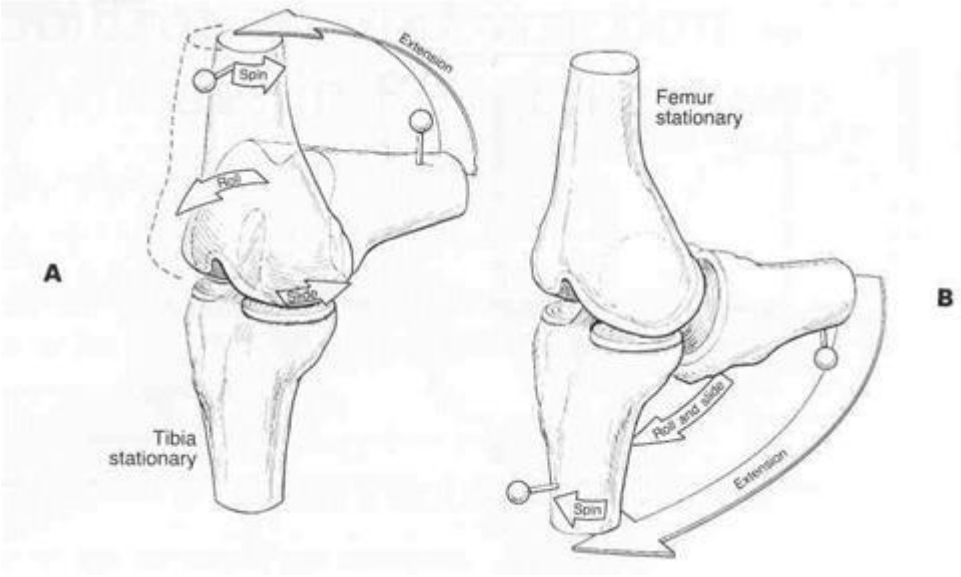
(a) Fibrous: There is no cavity, or space, present between the bones, so most fibrous joints do not move at all. Example: sutures in head (synarthridal).

(b) Cartilaginous: Cartilaginous joints are those in which the bones are connected by cartilage. Example: coracoclavicular joint, pubic symphysis, or costochondral joint of ribs (amphiarthridal).

(c) Synovial: Synovial joints are the only joints that have a space between the adjoining bones. This space, referred to as the synovial (or joint) cavity, is filled with synovial fluid. Example: knee joint, hip joint, or shoulder joint (diarthridal).

(2) Loading & Stress Behavior. Joints can roll, spin, and glide. In a synovial joint, there is a combination of all three.





c. <u>Cartilage</u>. Cartilage is formed at the end of bone where two ends are in contact. They distribute the load over a wide area, which decrease the stress in the joint. It also allows for movements with minimal friction and wear. Some cartilage in the body increases stability by deepening the joint.

(1) <u>Structure</u>. Cartilage is made of chondrocytes and has 4 zones. Overall, cartilage is an isolated tissue without nerve, blood supply, and lymphatic channels. Therefore, this tissue does not heal or repair well.

80% of cartilage is water

(2) <u>Lubrication of Cartilage</u>. Lubrication is needed to reduce friction of the joint and creates a thin barrier between bones. Nutrients are delivered to the cartilage by the lubrication to the cartilage surface.

(3) <u>Wear and Degeneration</u>. Wear and degeneration may naturally occur over time but can be accelerated due to poor mechanics, form, or excessive exercise.

(a) <u>Load</u>: Cartilage is minimally affected with axial load/ tension. However, sheer is not tolerated well.

(b) <u>Stress</u>: Like bone, repetitive stress can lead to fatigue wear of the cartilage even when lubrication is present.

(c) Osteoarthritis (OA): Osteoarthritis of the joint may result from cartilage wear and degeneration. The ends of bone lose their smooth contacts and become rough and inflamed.

d. Tendons & Ligaments. Tendons, ligaments, and joint capsules surround, connect, and stabilize the joint. Ligaments and joint capsules connect bone to bone. The function of the tendon is to connect muscle to bone for transmission of force.

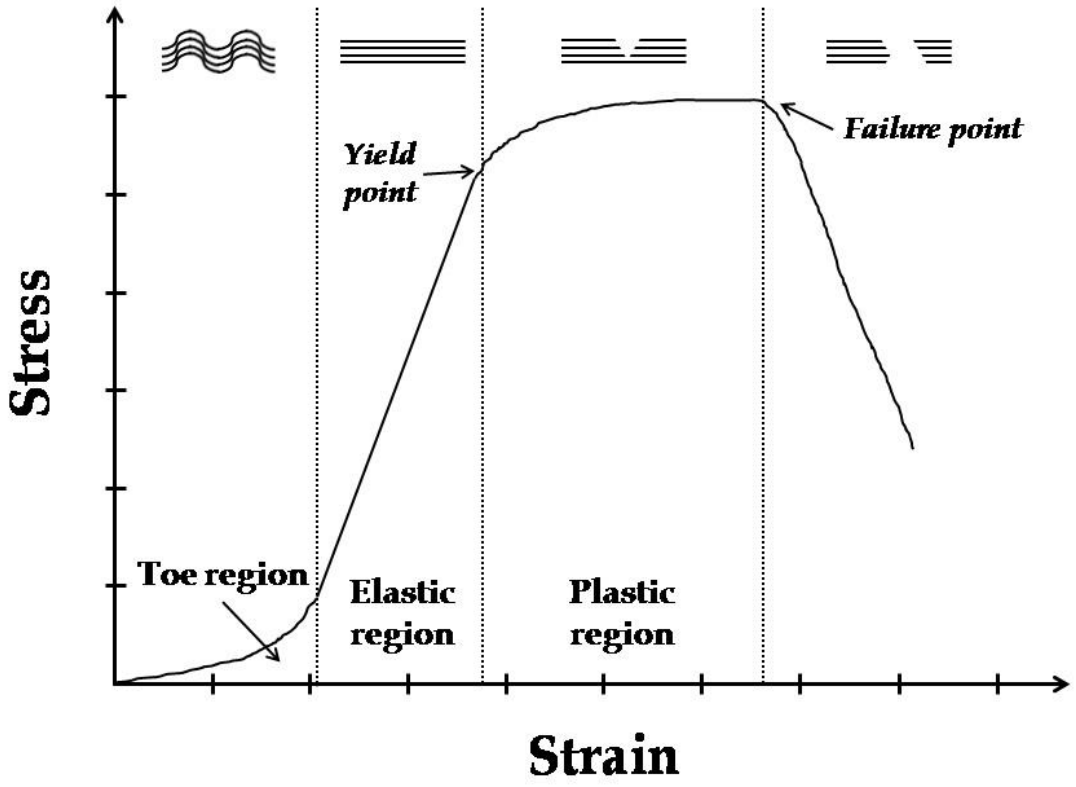
(1) Composition and structure. Tendons and ligaments are made of connective tissue.

(a) Vascular properties: Ligament and tendons have limited vascular properties which affects the healing process. They receive blood through peripherally.

(b) Order: Fibers are aligned in parallel which give them strength under tensile loads. Ligaments generally sustain loads in one predominate direction.

(c) Stability: Specialized receptors are located in tendons and ligaments which help with stability and proprioception.

(2) Elastic vs Plastic Region. Upon stretching the ligament or tendon they are able to resist load under tension. At some point there is a "plastic region", where the tissue no longer is able to return to it's normal length. Past that, there is a point of failure where the tissue ruptures.



(3) Factors that Affect Biomechanical Properties of Tendons and Ligaments. Tendon and ligament properties can change due to a number of variables.

(a) Maturation and Aging: As we age ligaments and tendons decrease their elastic properties.

(b) Mobilization and immobilization: Physical training has shown to increase strength and stiffness of ligaments and tendons. Immobilization has shown to decrease tensile strength in tendon and ligaments. Immobilization may have impact for several months to years on ligaments and tendons.

(c) Steroids: When corticosteroids are applied after an acute ligament injury; ligament stiffness decreases, energy absorption decreases, and the failure point decreases.

(d) Grafts: When a graft is used to repair or replace a ligament, it will take about 1 year for the healing process to complete. In theory, the graft should be stronger than the other side. Due to compliance or early return to training, the graft may actually have more laxity.

e. Nerve Roots and Nerves.

(1) Composition and structure: Nerves stem from the spinal cord and branch out to the rest of the body, similar to roots of a tree. There is an upper plexus and lower lumbar plexus in the body. Nerves follow a certain pattern and innervate certain muscles.

(2) Biomechanical Behavior of Peripheral Nerves: Nerves are strong with a considerable tension strength. Stretching injuries of a nerve typically occur with high energy impacts such as a motor vehicle accident. The damaged nerve can lead to decreased sensitivity and decreased motor strength. In extreme cases damaged nerves can cause atrophy and palsy symptoms.

2. FUNCTIONS OF HUMAN MUSCLE.

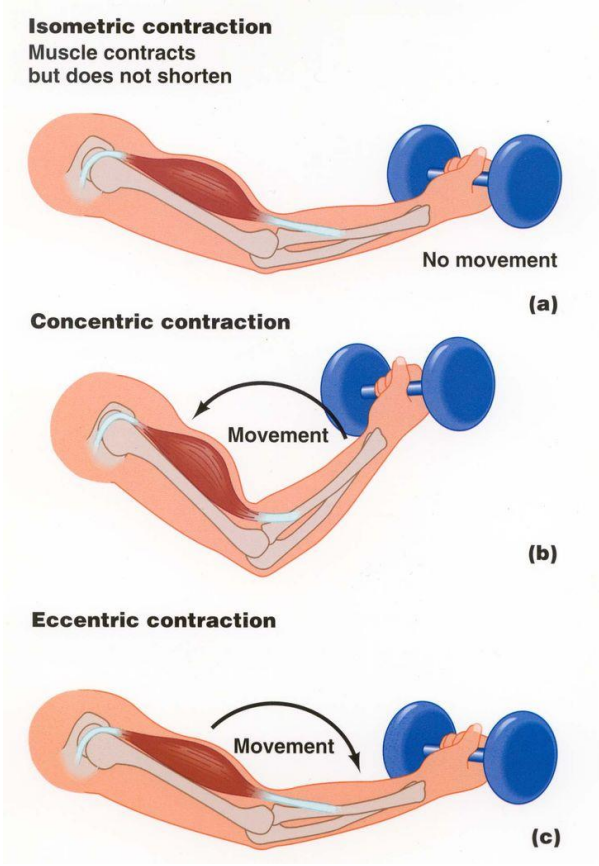
a. Composition and Structure. Muscles fibers have 4 characteristics: excitability, contractility, extensibility, and elasticity. Muscle tissue has the capacity to respond to a stimulus (excitable). Muscle tissue has the ability to shorten and generate pulling force (contractible). Muscle tissue can be stretched back to its original length (extensible). Muscle tissue has the ability to recoil to original resting length (elastic).

b. Types of Contraction.

(1) Isometric: Isometric contractions occur when there is no change in the length of the contracting muscle. This occurs when carrying an object in front of you as the weight of the object is pulling your arms down but your muscles are contracting to hold the object at the same level.

(2) Concentric: Concentric contractions are those which cause the muscle to shorten as it contracts. An example is bending the elbow from straight to fully flexed, causing a concentric contraction of the biceps brachii muscle. Concentric contractions are the most common type of muscle contraction and occur frequently in daily and sporting activities.

(3) Eccentric: Eccentric contractions are the opposite of concentric and occur when the muscle lengthens as it contracts. This is less common and usually involves the control or deceleration of a movement being initiated by the eccentric muscle's agonist.



c. <u>Roles of Muscle</u>.

(1) <u>Agonist</u>: The agonist in a movement is the muscle(s) that provides the major force to complete the movement. Because of this agonists are known as the 'prime movers'. In the bicep curl which produces flexion at the elbow, the biceps muscle is the agonist. The agonist is not always the muscle that is shortening (contracting concentrically). In a bicep curl the bicep is the agonist on the way up when it contracts concentrically, and on the way down when it contracts eccentrically. This is because it is the prime mover in both cases.

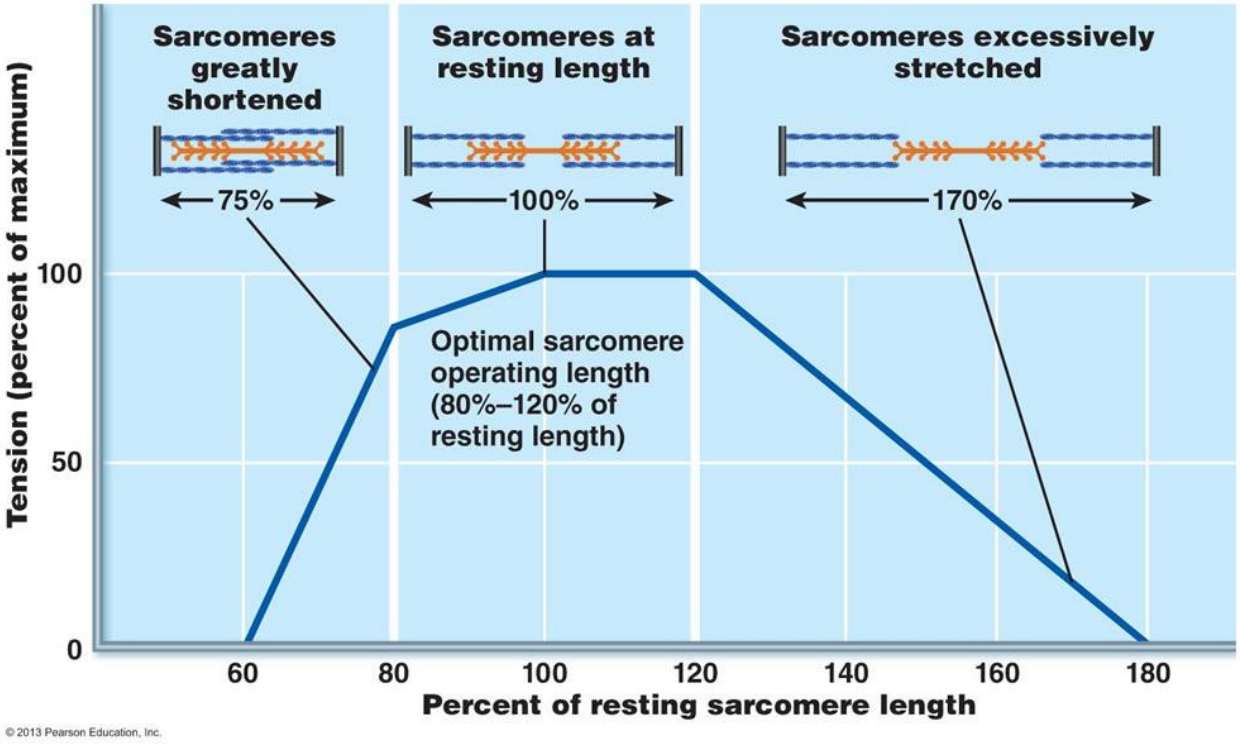
(2) <u>Antagonist</u>: The antagonist in a movement refers to the muscles that oppose the agonist. During elbow flexion where the bicep is the agonist, the triceps muscle is the antagonist. While the agonist contracts causing the movement to occur, the antagonist typically relaxes so as not to impede the agonist. The antagonist doesn't always relax though, another function of antagonist muscles can be to slow down or stop a movement. We would see this if the weight involved in the bicep curl was very heavy, when the weight was being lowered from the top position

the antagonist triceps muscle would produce a sufficient amount of tension to help control the movement as the weight lowers.

(3) Stabilizers: The synergist in a movement is the muscle(s) that stabilizes a joint around which movement is occurring, which in turn helps the agonist function effectively. Synergist muscles also help to create the movement. In the bicep curl the synergist muscles are the brachioradialis and brachialis which assist the biceps to create the movement and stabilize the elbow joint.

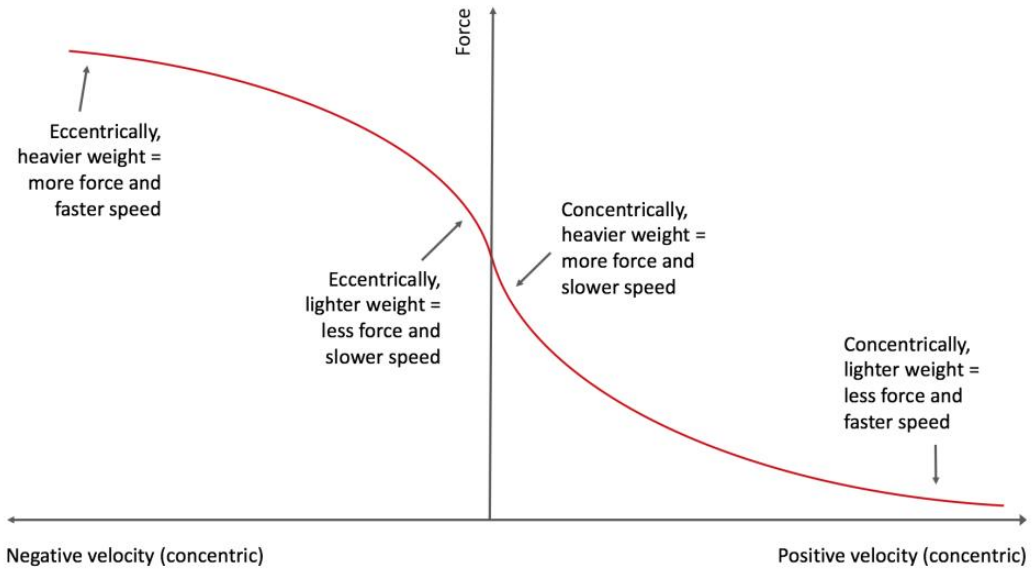
d. Muscle and Force Relationships.

(1) Length-force relationship: This relationship is between a muscle's length and the isometric tension (force) which it generates when fully activated.

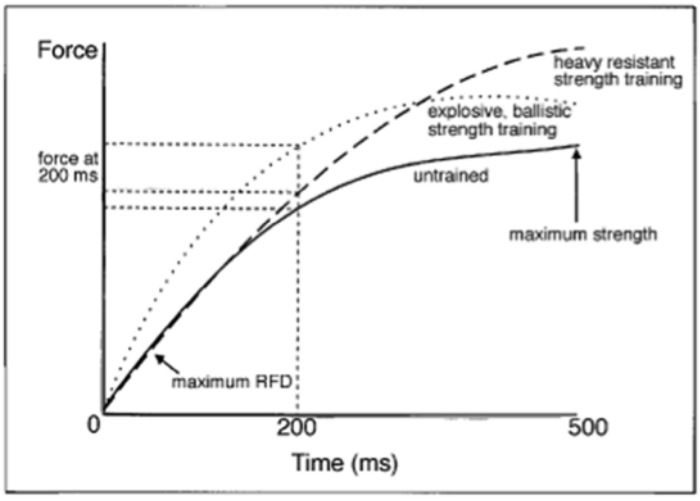


(2) Force-velocity relationship: Being hyperbolic means that the rate of change of force alters with changing velocity. At low velocities, the rate of change of force is very high and it drops off quickly with small increments in speed. At higher velocities, the rate of change of force is quite low and alters little with each incremental change in speed. The hyperbolic force velocity relationship describes the relationship between muscle force production and contractile velocity in single

muscles while shortening. Therefore it does not necessarily explain the relationship between joint moments and joint angular velocity, nor does it explain the relationship between muscle force production and contractile velocity in single muscles while lengthening.



(3) Force-Time relationship: The force generated by a muscle is proportional to the contraction time: the longer the contraction time, the greater the force developed.



e. Muscle Effects.

(1) Effect of pre-stretching: Muscle performs more work when it shortens immediately after being stretched in the concentrically contracted that than when it shortens from a state of isometric contraction. Phenomenon is not only accounted by elastic properties.

(2) Effect of temperature: Increases conduction velocity and increases the frequency of stimulation in the neurological system; therefore, increasing force production. Increases greater enzyme activity of metabolism. Muscle fiber temperature increases by blood flow (warm up) and production of heat from metabolism. (contraction fiction)

(3) Effect of fatigue: If a muscle has adequate oxygen supply and nutrients that can be broken down to ATP, it can sustain itself. The frequency must be low enough where ATP can synthesize at a rate to keep up with ATP breakdown during contraction.

(a) If the frequency of stimulation increases and outpaces the rate of replacement; muscle responses grow progressively weaker.

(b) Fatigue is first observed by a lack of coordination of movement and its effect in the increase loads of the tissue.

(c) Skills of the individual decrease.

(d) Decrease in accuracy control and speed of contraction, which may predispose an individual to injury.

f. Muscle Remodeling. Muscle, like other tissue has the ability to remodel and change.

(1) Disuse and immobilization. If the muscle is not used, there will be a negativ effect on the muscle tissue.

(a) Loss of muscle endurance and strength

(b) Atrophy: decrease in muscle size and number of fibers

(c) Biomechanical changes in anaerobic and aerobic capacity

(b) Effects of physical training. If the muscle is used and exercised, there will a positive effect to the muscle.

1. Increases the cross sectional area of all muscle fibers.
2. Some evidence that fiber types may adapt depending on training.
3. Stretching increases the muscle flexibility, increases elasticity, and the length of the muscle-tendon unit.

SUMMARY: When force and resistance are acting on the body, there are accommodations and changes that occur across human tissue. Tendons and ligaments increase stability of a joint and help transmit force to the limb. They also have limits before tearing. There is a variety of resistance training techniques, the muscle fiber is able to accommodate depending on the stimulus.

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