Applications of Statics to Biomechanics

Joints

The human body is:

- Rigid (i.e. it can maintain posture)
- Flexible (i.e. it can change its posture and move)

The flexibility of the human body is due primarily to the:

- Joints
- Articulations of the skeletal system

The primary function of joints is to:

- Provide mobility to the musculoskeletal system\
- Provide stability

Classification of the skeletal system may be based on the structure and/or function. Synarthrodial joints are formed by two tightly fitting bones, which don't allow any relative motion of the bones forming them. (ex. Bones of the skull).

Amphiarthrodial joints allow slight relative motions, and feature an intervening substance (a cartilaginous or ligamentous tissue) whose presence eliminates bone-to-bone contact (ex. Bones found between the vertebrae).
Diarthrodial joints are mechanically the most significant type of articulations. They permit varying degrees of relative motion and have:

- Articular cavities-space between articulating bones
- Ligamentous capsule-holds articulating bones together
- Synovial membrane-the internal lining of the ligamentous capsule, enclosing the synovial fluid which is a viscous material which reduces friction, wear and tear of the articulating surfaces, and nourishing the articular cartilage lining the surfaces.

Stability of the joint is dependent on:

- The manner in which the articulating surfaces fit together
- The structure of the capsular ligament
- The structure and length of the ligaments around the joint and
- The degree to which muscles around the joint can be stretched.

Lever Systems. When muscles, joints, and bones interact to generate movement, they form biological lever systems. A lever is a structure that can pivot around a point, called the *fulcrum*, when force is applied. In the body:
Contraction is the development of tension. In engineering mechanics it implies the shortening under compressive forces. In muscle mechanics, contraction can occur as a result of:

- Muscle shortening or lengthening
- Without any change in the muscle length

Various types of muscle contractions exist, such as:

- Concentric: occurs simultaneously as the muscle length decreases

Ex. Biceps during flexion of the forearm

- Statics Contraction: Muscle length remains constant

Ex. Biceps when forearm is flexed

- Eccentric Contraction: Muscle length increases

Ex. Biceps during extension of forearm

Muscle can also be named according to the functions they serve.

- Agonist-if it causes movement through concentric contraction
- Antagonist-result of eccentric contraction, control the movements

Each moveable bone is flanked by two muscles or muscle groups that move it in opposite directions and are therefore termed *antagonistic muscles*. The muscles for the upper arm, for example, form an antagonistic pair. When you contract the biceps, your arm bends at the elbow. When you contract the triceps, your arm straightens. Usually, one member of the antagonistic pair is stronger than the other.

Basic considerations. Forces involved in the human body can be grouped as internal and external.

- Internal is the association of muscles, ligaments and tendons
- External is effect of gravity on the body or its segments, forces applied during stretching, and forces applied by prosthetics.

The unknowns in static problems involving the muscoskeletal system are the joint reaction forces and muscle tensions. Mechanical analysis of a joint requires:

- Knowledge of the vector characteristics of tension.
- Proper locations of muscles attachments.
- Weights or masses of body segments.
- Centers of gravity of the body of segments.
- Anatomical axis of rotation of the joint.

Mechanics of the shoulder. The shoulder forms the base for all upper extremity movements. Its complex structure can be divided into:

- Shoulder joint
- Shoulder girdle

Shoulder joint is also known as the glenohumoral articulation [a ball-and-socket joint]. Nearly hemispherical humeral head (ball) and the shallowly concave glenoid fossa (socket) of the scapula.

Movements are:

- Extension
- Adduction
- Inward rotation

Mechanics of the Elbow. The elbow joint is composed of 3 separate articulations:

- **Humeroulnar joint** (is a hinge), allows only uniaxial rotations confining the movements about the elbow joint to:
  - Flexation-movement of the forearm towards the upper arm, and
  - Extension-movement away from the upper arm
- **Humeroradial joint** (a hinge)
- **Proximal rodioulnar joint** (a pivot joint) allows the radius and ulna to undergo relative rotation giving rise to pronation and supination.

Muscles that coordinate and control movement of the elbow joint:

- Biceps-the most powerful flexor of the elbow joint
- Brachialis muscle- (another flexor)
- Triceps-control the extension movement of the elbow
- Pronator teres-Pronation and supination movement
- Supinator teres-Pronation and supination movement

Common Injuries of the elbow are fractures and dislocations as “tennis elbow” which occurs as a result of repeated and forceful pronation and supination movements of the elbow.

Mechanics of the spinal column. The spinal column is the most complex part of the human muscoskeletal system. It consists of:

- Cervical (neck)
- Lumbar (lower back) sacral
- Thoracic (chest)
- Coccygeal regions

The vertebral column consists of 24 vertebrae. A fibrocartilaginous disk is interposed between each pair of vertebrae.

- Bones function as levers
- Joints are fulcrums
- Skeletal muscles supply the force.

Force generated in the muscles passes to the bones by way of the attached tendons. A skeletal muscle is attached to one end of each of two bones by its tendons.

- The **origin** is the end on the bone that does not move
- The **insertion** is on the end of the moveable bone.

The muscular system consists of three muscle types:

- Cardiac muscle, which composes the heart
- Smooth (nonstraited or involuntary) muscle, which lines the hollow internal organs
- Skeletal (straited or voluntary) muscle, which attaches to the skeleton via the tendons and causes it to move.

Skeletal muscle is the most abundant tissue in the human body, accounting for 40 to 45% of the total body weight. There are more than 430 skeletal muscles, found in pairs on the right and left sides of the body. The muscles provide strength and protection to the skeleton by distributing loads and absorbing shock, and they enable the bones to move at the joints.

The skeletal muscles perform both dynamic and static work. Dynamic work permits locomotion and the positioning of the body segments in space. Static work maintains body posture.

Structure and Organization of Muscle. The structural unit of skeletal muscle is fiber, a long cylindrical cell with many hundreds of nuclei. Muscle fibers range in thickness from about 10 to 100 um and in length from about 1 to 30 cm, the longest fibers being found in the sartorius muscle.

Each muscle fiber is composed of a large number of delicate strands, the myofibrils. These are the contractile elements of muscle. Their structure and function have been studied exhaustively by light and electron microscopy, and their histochemistry and biochemistry have been explained.

Muscle exhibits viscoelastic behavior. They are elastic in the sense that when a muscle is stretched and released it will resume its original (unstretched) size and shape. Muscles are viscous in the sense that there is an internal resistance to motion. Movement of human body segments is achieved by skeletal muscle.

- Skeletal muscle is composed of muscle fibers and myofibrils.
- Myofibrils are made of actin and myosin filaments.

Skeletal muscle is attached by tendons to at least 2 different bones. When muscle fibers contract under the stimulation of a nerve, the muscle exerts a pulling effect on the bones to which it is attached.