REVIEW OF HUMAN MUSCULOSKELETAL SYSTEM

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ABSTRACT

This paper reviews the basic principles, functions and structure of the musculoskeletal system. The main purpose of this study is to review the tools for mechanical analysis and to understand behavior of the tissues and structural units that comprise to form a musculoskeletal system. All the major contributing components of musculoskeletal system such as bones, joints, muscles, tendons and ligaments have been discussed. Biomechanics these study of response of biological system when subjected to mechanical forces. By understanding and applying the biomechanical properties of musculoskeletal system normal movement on each part of body could be understood.

Keyword: - *Biomechanics, Musculoskeletal System***.**

1. INTRODUCTION

All living organisms have systems that not only support and protect their body parts but also allow and assist the movement. Such systems are known as skeletal system. Generally skeletal system is classified in two broad types:

1. Exoskeleton,
2. Endoskeleton.

Exoskeleton is usually a hard outer layer comprised of chitin to give support and keep their body inside it. Due to this structure the organs and body become too heavy for larger animals. Hence, this type of skeletal system is generally observed in smaller insects only. Larger land dwelling animals are equipped with endoskeleton for support. It also acts as a system that allows transfer of forces with help of muscles, and provides protection for vital organs such as ribcage for heart and skull for brain.

The major components of a musculoskeletal system are:

1. Bone,
2. Muscle,
3. Joint,
4. Ligament,
5. Tendon.

The bones provide rigidity while protecting and supporting most of soft tissues which provide leverage through actions of muscles, permitting the movement of the body. Bones are also connected to each other forming joints allowing various degrees of freedom, based on their structure. Some joints are stabilized by fibrous tissues while others are stabilized by tough but flexible ligaments. Muscles are attached to bones by strong and flexible yet inextensible tendons which are inserted into bones.

2. BONE

Structural Composition of bone is responsible for mechanical property of the bones. Bone is composed of two main components: Collagen and Hydroxypatite [1]. Bone in general is made up of 40% organic components and 60% inorganic components. Collagen forms over 90% of organic weightage while Hydroxypatite forms most of inorganic weightage. Hydroxypatite is a ceramic component in nature and hence bones exhibit certain ceramic properties.

The Structure of human bone changes with age. So, bone in adult is different from that of children. The bone in children has randomly distributed fibers making it strength in all directions. They are much more flexible than adults, probably to provide safety for all the tumbling and falling. They are known as woven bones. However, adult bones have more strength. [2]

Once the woven bones become mature, they are classified as: Cortical bones and Cancellous bones. Cortical bone is hard and dense while cancellous bone is not as dense and comprises of spaces. Cancellous bone generally resists the primary loading a bone is subjected to. Hence, cancellous are located at places like interior femoral head while cortical bones for midshaft of femur.

2.1 Mechanical Properties of Bone

Mechanical properties of bone change with location as well as type of bone. Thus individual case by case study is required to foe analysis of a specific bone. However, behavior can be predicted using general structural properties. Bone such as femur is a major weight bearing bone in the body. The load acting on femur changes with certain activities such as walking, sitting, squatting or stair stepping. Due to asymmetric shape of bone, the load acting on femur is generally eccentric in nature. Thus, the additional moment also acts on it. Hence, such bone must have mechanical property to withstand loads that are several times more than the body weight. The major load in femur is compressive in nature, while eccentricity adds tensile and activities superimpose bending loads. Also, bone must withstand certain amount of impact loads (as in accidents) .

Bone is an anisotropic material, the property of material change with change in directions. As bone is made up of composite material, HA behaves like ceramic material having greater tensile and compressive strength. The collagen induces viscoelastic behavior and adds to the tensile strength.

3. Muscle

Skeletal Muscle converts chemical energy to mechanical energy for following functions:

1. Movement Generation
2. Force Generation
3. Endurance

Muscle and Force Generation is mechanical outcome of contractions. Muscle is long cylindrical cell comprised of smaller units of filaments having multinucleated structure. Although the generative properties are due to chemical reaction of filaments and fibers, the scope of this work restricts an detailed discussion on that aspect. But, we can safely say that muscle force generation is due to contraction of fibers on receiving an electrical stimuli via neurological pathways.

The major factors affecting muscles ability to produce motion are

1. The length of fibers of the muscle
2. Muscle's Moment Arm

The absolute amount of shortening a muscle undergoes is a function of muscle fiber length. Also the fiber arrangement can be broadly classified as two major types, parallel and pennate. Fibers within the parallel muscle are almost parallel to its entire muscle length with less prominent tendons. It has two subtypes Strap and Fusiform.

While the pennate muscles have various arrangements such as unipennate, bipennate and multipennate. Pennate muscles have tendons almost along whole length and muscle fibres arranged in oblique manner to it.

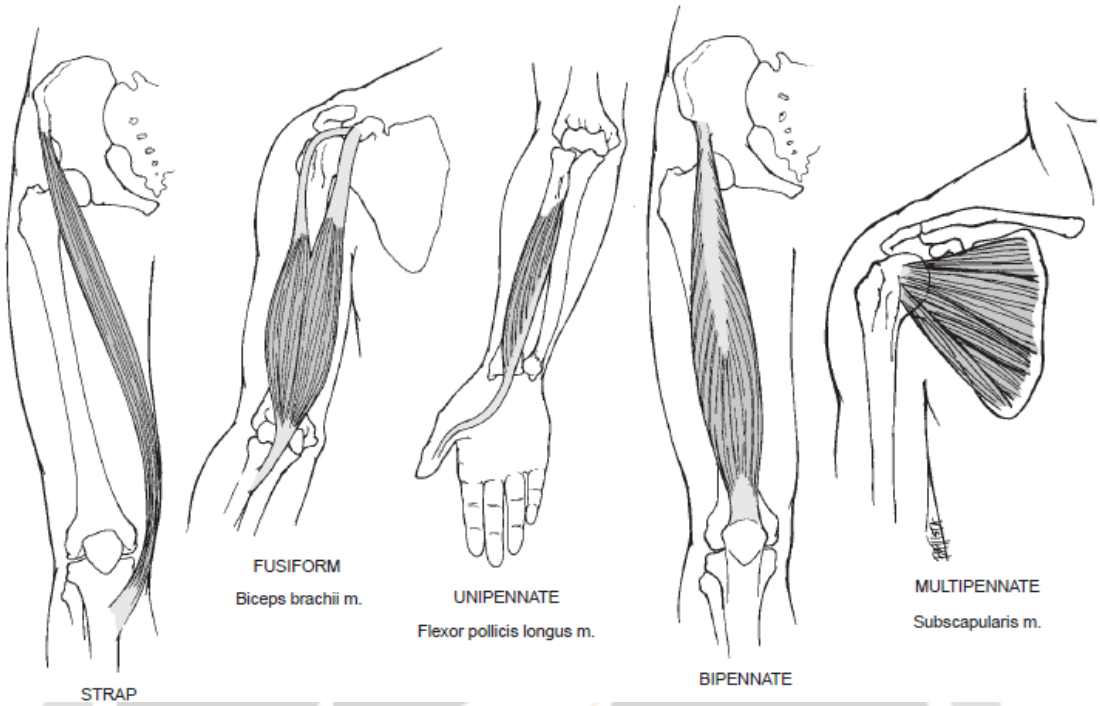
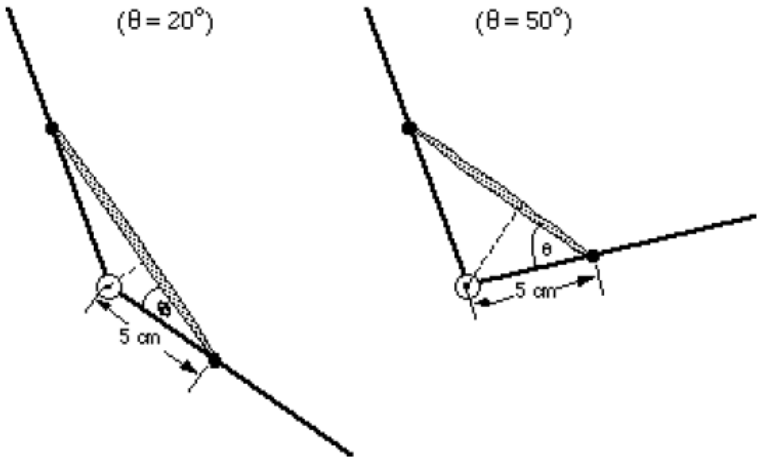


Figure 1 Types of muscle fiber arrangements [1]

Muscle moment arm is an instantaneous measure of the effectiveness with which the contraction force of a given muscle can generate a torque at a "joint of interest." [3]. Moment arm depends on location of muscles attachment on the bone and angle between line of action of muscle and insertion point across the joint on the bone. It has major effect on excursions produced by contraction of muscle. Muscle having short moment arm will produce higher moment arm than a muscle with longer moment arm with same contraction capacity.



.**Figure 2** Oversimplified view of moment arm [4]

Muscle strength, including its tensile force of contraction and its resulting moment, is a function of muscle size, muscle moment arm length, stretch of the muscle, contraction velocity, fiber types within the muscle, and amount of muscle fiber recruitment.

4. JOINT

Joint are structures which allow the motion between two articulating bones. The major purpose of joint is to allow movement between two rigid structures without affecting the structural integrity and stability of the entire body. [5] Amount of mobility that a joint allows varies vastly. The major classifications of joints are:

1. Diarthroses : allow motion between bones,
2. Syanthroses: allow limited or no motion between bones.

Joints generally have external fibrous layer and inner synovial layer forming a capsule like structure which is filled with synovial fluid to lubricate the mating parts. Some joints have a cushion like structure to reduce striking of bones and that structure is known as meniscus. Ex. Knee Joint.

Major joint motions that are allowed are Translation, Rotation and combination of both of them. The measure of joint capacity is the degree of freedom a joint allows.[6]

5. LIGAMENT AND TENDON

Tendons and ligaments provide and maintain form in the body. They induce passive and dynamic stability to joints. The main function of ligament is to make a joint stable, it can withstand increased stress loading. Ligament failures or mislocation can cause severe injuries. (Ex. ACL injury in athletes). Tendons are the connecting tissus between bones and muscles. They transfer the forces exerted by the muscles to the bones.

6. CONCLUSION

All the individual systems and components discussed above combine to form musculoskeletal system. The understanding of which is important from both clinical as well as engineering perspectives. Better understanding would lead to better prosthetic designs as well as allow better opportunities in understand behavior of human body during repetitive process and hence ergonomics and even for crash testing and simulation studies.

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