**Onyedum Udoka**

**April, 2020.**

**Research Term Paper**

**Soft Tissue Mechanics (STM)**

**Introduction**

Any solid component of a living organism, from bones to cells, may be considered as a living tissue. Soft tissues are distinguished from other tissues like bones, for their flexibility and their soft mechanical properties. Soft tissues include connective tissues, muscles, organs and the brain. The functions of soft tissues in an organism also greatly differ from that of hard tissues. Bones build the rigid skeletal structure of the body, cartilage to lubricating the articulations, skeletal muscles to producing strength and to moving the skeleton through the tendons, and organs and brain play physiological functions to maintain and control the organism. In this term paper, we go over the types of soft tissues in the human body, their general composition, and their mechanical properties, as relates to stress and strain.

**Soft Tissue in The Human Body**

Soft tissue refers to tissues that connect, support, or surround other structures and organs of the body. Soft tissue includes tendons, ligaments, fascia, skin, fibrous tissues, fat, and synovial membranes, and muscles, nerves and blood vessels

There are different types of soft tissue found in the body.

1. **Fat**

Fat is a soft tissue made up of fat cells (adipocytes) that are packed tightly together. It may also be called fat tissue or adipose tissue. Fat is commonly found under the skin of the buttocks, hips, waist and abdomen. It also surrounds organs, such as the kidneys. Fat cushions the body, provides padding between organs and helps keep the body warm. The body also stores fat and uses it for energy when you need it.

1. **Fibrous tissue**

Fibrous tissue is connective tissue made up of rope-like parts called fibres. These fibres help move body parts and keep them strong and stable. Tendons (which attach muscle to bone) and ligaments (which attach bone to another bone) are made up of fibrous tissue. Fibrous tissue is also found in the walls of blood vessels and surrounds many organs.

1. **Muscle**

There are 3 types of muscle – smooth muscle, skeletal muscle and cardiac (heart) muscle.

1. Smooth muscle works automatically without you thinking about it (involuntary muscle). It is found in the walls of the body’s hollow organs, such as the stomach, intestines, bladder, uterus and blood vessels. Smooth muscle allows organs to expand and contract as needed.
2. Skeletal muscle is a type of muscle that you control to move your body (voluntary muscle). It is found mainly in muscles that attach to bones. Some skeletal muscles in the face attach to the skin. Skeletal muscle keeps the skeleton together and helps you stand upright. It also allows you to move different parts of your body, such as your arms and legs.
3. Cardiac muscle forms the walls of the heart and allows the heart to pump blood. Cardiac muscle works automatically without you controlling it.
4. **Synovial tissue**

Synovial tissue is thin and loose connective tissue that lines joints, such as elbows and knees. It is also found around tendons and fluid-filled sacs between bones and tendons (bursa). Synovial tissue makes synovial fluid, which is a thick liquid that allows areas to move easily.

1. **Blood vessels**

Blood vessels are long, elastic hollow tubes that are found throughout the body. Arteries, veins and capillaries are types of blood vessels. Blood travels through blood vessels and carries oxygen, nutrients, hormones, waste and other products around the body.

1. **Lymph vessels**

Lymph vessels are small tubes like blood vessels that run throughout the body. They contain lymph fluid to collect and carry waste products, germs and damaged cells away from the body’s tissues.

1. **Nerves**

Nerves are soft tissues that control all of the body’s functions and movements. Nerve tissue is made of 2 main types of cells – nerve cells (neurons) and glial cells (neuroglial cells). Nerve cells send messages (as electrical impulses) from one part of the body to another. Glial cells support the nerve cells.

**Basic Structural Elements of STM And Collagen as A Fibrous Protein**

Soft connective tissues of our body are complex fiber-reinforced composite structures. Their mechanical behavior is strongly influenced by the concentration and structural arrangement of constituents such as collagen and elastin, the hydrated matrix of proteoglycans, and the topographical site and respective function in the organism. [1]

Collagen is a protein which is a major constituent of the extracellular matrix of connective tissue. It is the main load carrying element in a wide variety of soft tissues and is very important to human physiology Collagen is the most abundant protein in the body, accounting for greater than 30 percent of protein in the human body, and the largest component of the ECM, where it serves an essential structural role as provider of tensile strength to tissues and organs. It also plays an important role in the elasticity of a limited number of tissues, especially in tendons [2]

Collagen is a macromolecule with length of about 280 nm. Collagen molecules are linked to each other by covalent bonds building collagen fibrils. Depending on the primary function and the requirement of strength of the tissue the diameter of collagen fibrils varies [1] For instance, In the structure of tendons and ligaments, collagen appears as parallel oriented fibers, while many other tissues have an intricate disordered network of collagen fibers.

**Stress-Strain Relationship in Collagen Biomaterials**

Stress and strain measurements are employed in biomaterials, using mechanical methods, in order to determine other mechanical properties of the materials. The extension (strain) exhibited by a given material is measured upon the application of a force (stress), resulting in the collection of a stress–strain curve from which physical properties can be determined

A typical stress–strain curve is J-shaped, where the initial “softer” response is due to entropic elastic deformation and the latter stiffer response correlates with molecular deformation (changes in internal energy), which is followed by plastic deformation and rupture of the material [2]. The typical curves for collagen exhibit a classic J-shape with a small entropic response (typically below strains of about 3%) and a substantial molecular stretching component, which adopts linearity at higher levels of strain.

**Cartilage and Its Applications in Articulating Joints**

Cartilage is a group of tissues produced by chondrocytes that is characterized by a relative lack of vascularity and consists of cells surrounded by a specialized extracellular matrix composed predominantly of type II collagen and proteoglycan [3] Cartilage is a supporting connective tissue that, together with the bone, forms the framework supporting the body as a whole.

Cartilage is a specialized connective tissue present in animals, including humans, distinct from connective tissue. Proper cartilage tissue is stiff but also flexible. As a result, it is an integral part of many parts of the body where the supporting structures must accommodate limited movement.

**Mechanical Testing Procedures for Soft Tissues**

Although the mechanical properties of tissue-engineered scaffolds are of great importance, many human tissues that undergo restoration with engineered materials have not been fully biomechanically characterized. Several compressive and tensile protocols are reported for evaluating materials, but with large variability it is difficult to compare results between studies

Whilst an understanding of tissue failure is important, it is also important to have knowledge of the elastic and viscoelastic properties under more physiological loading conditions.

To understand the compressive and tensile properties of a tissue, the Young's elastic modulus is typically calculated by analyzing the linear portion of the stress-strain curve, indicating the elastic resistance to compression or tension. There are currently several testing regimes currently used to test the mechanical properties of bio materials. Many mechanical methods currently focus on characterizing the mechanical properties of the tissue by testing the specimen to destruction [4]

**References**

|  |  |
| --- | --- |
| [1] | G. A. Holzapfel, "Biomechanics of Soft Tissue," Graz University, Austria, 2007. |
| [2] | M. D. Lisa and K. W. Fred, "Molecular assembly and mechanical properties of the extracellular matrix: A fibrous protein perspective," *Biochimica et Biophysica Acta (BBA) - Molecular Basis of Disease,* pp. 866-875, 2013. |
| [3] | B. D. Barbra and M. Doroudi, "Cartilage," *Vitamin D (Third Edition),* pp. 507-519, 2011. |
| [4] | G. Michelle, P. Yaami, S. Alexandar, E. b. Peter and S. Mattheew, "Biomechanical Characterization of Human Soft Tissues Using Indentation and Tensile Testing," *Journal of Visualized Experiments,* 2016. |
| [5] | B. S. Richard, "The Structure of Collagen Fibrils," *Advances in Protein Chemistry,* pp. 69-150, 1952. |