

University of Hillah

The first stage

Medical physics



Physics of the Skeleton

Ms.c Muntazer Ahmed

Introduction:

At its core, the physics of the skeleton explores how forces, stresses, and strains interact within the skeletal framework to support the body, facilitate motion, and withstand external loads by applying principles of mechanics, such as statics and dynamics.

Understanding the physics of the skeleton is crucial for a spectrum of disciplines, ranging from orthopedics and sports science to biomechanical engineering and forensic anthropology. By studying how bones respond to mechanical stimuli, researchers can unravel the mysteries of bone growth, remodeling, and repair, paving the way for innovative treatments for skeletal disorders and injuries.

Moreover, the physics of the skeleton sheds light on the intricate relationship between bone structure and function.

The Role of Physics in Understanding Bone Health and Injury:

Applying physical principles to the study of the skeleton has significant implications for understanding bone health and injury. By analyzing the mechanical behavior of bones, researchers can:

- 1. Optimize Bone Design:** Engineers can design artificial implants and prostheses that mimic the mechanical properties of natural bone, improving their integration and performance.
- 2. Predict Fracture Risk:** By studying the factors that influence bone strength, researchers can develop tools to assess an individual's risk of fracture and implement preventive measures.
- 3. Develop Effective Treatments:** Understanding the mechanisms of bone healing can inform the development of therapies to promote bone regeneration and repair.

4. **Enhance Athletic Performance:** By analyzing the biomechanics of movement, sports scientists can optimize training regimens and equipment to reduce the risk of injury and improve performance.

Bones function in the human body:

1. **Support:** Bones provide structural support for the body. They form the framework that supports and anchors muscles, organs, and tissues.

2. **Protection:** Bones protect vital organs such as the brain, heart, and lungs. For example, the skull protects the brain, and the rib cage shields the heart and lungs.

3. **Movement:** Bones, along with muscles, facilitate movement. Muscles pull on the bones to produce movement at joints.

4. **Mineral Storage:** Bones act as a reservoir for minerals, especially calcium and phosphorus. These minerals can be released into the bloodstream when needed for various bodily functions.

5. **Blood Cell Formation:** The bone marrow inside certain bones is responsible for the production of blood cells, including red blood cells, white blood cells, and platelets.

6. **Fat Storage:** Some bones store fat in the yellow bone marrow, which can serve as an energy reserve.

7. **Endocrine Regulation:** Bones produce hormones that help regulate various physiological processes, such as bone growth, glucose metabolism, and energy expenditure.

Bones are primarily composed of two main components:

1. **Organic Matrix:** This component consists of about 30% of the bone's weight and is primarily made up of collagen fibers. Collagen provides flexibility and tensile strength to the bone, preventing it from being brittle.
2. **Inorganic Matrix:** This component makes up about 60% of the bone's weight and is primarily composed of calcium phosphate in the form of hydroxyapatite crystals. Hydroxyapatite provides the bone with its hardness and compressive strength.
3. **Water:** About 10% of the bone's weight is water, which helps maintain the bone's structure and allows for nutrient exchange.

Bone Fractures:

A common occurrence in both the young and the elderly, represent a significant health concern worldwide. These injuries can result from traumatic incidents, or underlying medical conditions, leading to pain, dysfunction, and sometimes long-term complications. Understanding the types, causes, and treatment of bone fractures is essential for healthcare professionals in providing effective care and promoting healing.

Why do some people's bones break more readily than others?

There are several reasons:

1. Differences in Bone Strength

They could have different intensive properties. For example, they could be more porous and concomitantly have lower damage thresholds—such as for those with osteoporosis, which is common in older people who have lost much calcium.

2. Bone Thickness and Genetics

They could have different extensive properties, such as thinner bones. Part of this is clearly genetic in origin, but some is developmental. Bones become thicker in children who are physically active, and who are consequently applying loads to them while they are growing. In fact, the bones in the arm wielding the tennis racket can be ~30% thicker than those in the other arm in adults who played tennis as youngsters.

3. Chance and Complexity of Body Materials

They could have bad luck. Reason (a) is related to why body materials are complex. They are composite materials, composed of different types of materials on a microscopic basis, that depend on life experiences. Bone is a composite composed of calcium-based inorganic matter and organic matter.

Types of bone fractures resulting from different types of loading

DIRECT FRACTURES



LOW ENERGY
Transverse with
little or no comminution



HIGH ENERGY
Markedly comminuted
with soft tissue injury

INDIRECT FRACTURES



TRACTION
Transverse fracture
perpendicular to force



BENDING
Transverse with
butterfly fragment



TORSION
Spiral fracture



BENDING AND TORSION
Oblique fracture

Mechanical properties of bone are:

1) Density

Throughout life, the density of compact bone remains remarkably consistent at approximately 1.9 g/cm^3 (equivalent to 1.9 times the density of water). As individuals age, bones may become more porous and lose density from the inner or periosteal surface. Despite this, the density of the remaining compact bone typically remains around 1.9 g/cm^3 . The decrease in strength is primarily due to thinning rather than reduced density. It is important to note that bone density, a physical measure, is frequently mistaken for bone mass.

2) Bone's Mechanical Response to Stress

When a sample of fresh bone is subjected to tension or compression, it undergoes changes in length. Initially, the strain (the change in length relative to the original length) increases linearly with the applied stress (force per unit area), adhering to Hooke's Law. This linear elastic region indicates that the bone is deforming elastically, returning to its original shape when the stress is removed.

As the stress continues to increase, the bone enters a plastic deformation phase. In this region, the strain increases more rapidly than the stress, and the bone begins to undergo permanent deformation. Eventually, the stress reaches a critical point, known as the ultimate tensile strength, where the bone fractures. For bone, this ultimate tensile strength is approximately 120 N/mm^2 .

Young's modulus (Y) is a measure of the stiffness of a material. It is defined as the ratio of stress to strain in the linear elastic region of the stress-strain curve. A higher Young's modulus indicates a stiffer material, meaning it requires a greater stress to produce a given amount of strain.

Ex: Bone has a Young's modulus of (18×10^9) Pa .Under compression, it can withstand a stress of about (160×10^6) Pa before breaking. Assume that a femur (thigh bone) is (0.5 m) long, and calculate the amount of compression this bone can withstand before breaking.

Sol/ the bone can withstand a compression of about 4.45mm before breaking.