Medical physics module semester 1

Session 1

Lec.2

Physics of The Skeleton

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Objectives

- After the end of this lecture, the student must know:

  1- The different function of bones in the body.

  2- Calcium homeostasis and the role of calcium in bone formation and strength.

  3- Measurement of bone mineral.

Bones

Bone is of interest to medical physics and engineers.

Perhaps this organ system of the body appeals most to physical scientists because engineering type problems dealing with static and dynamic leading forces that occur during standing, walking, running, and lifting.

Obj.1 Functions of Bones

1- Support. Support function is most obvious in the legs.

2.Locomotion. Bone joint permit movement of one bone with respect to another.

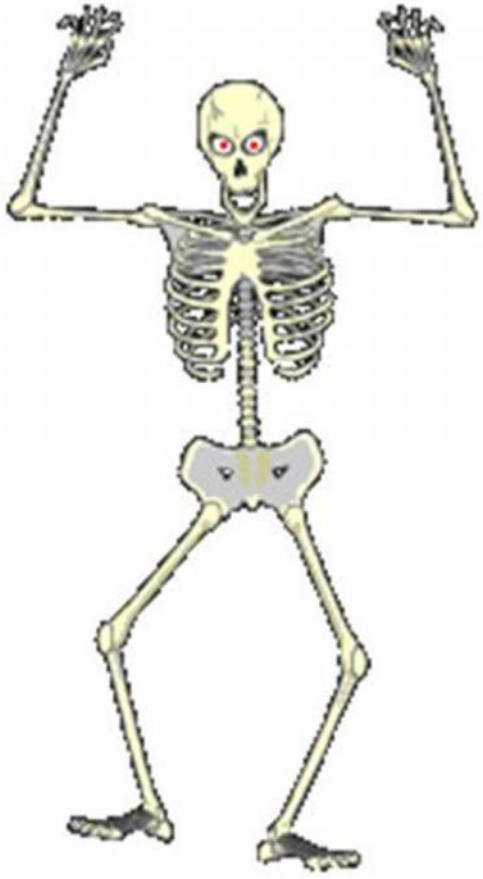
3-Protection of various organs. The skull, which protects the brain and several of the most important sensory organs (eyes and ears).

4.Storage of chemical. The bone acts as a chemical bank for storing elements for future use the body.

5. Nourishment. The teeth are specialized bones that can cut food.

6. Sound transmission. The smallest bones of the body are the ossicles in middle ear.
These three small bones act as lever and provide an impedance matching system for converting sound vibrations in air to sound vibrations in the fluid.

Functions of Bones



- **Support** – hard framework that supports body & cradles soft organs
- **Protection** – fused bones of skull, vertebrae, rib cage
- **Movement** – skeletal muscles use bones as levers
- **Mineral Storage** – calcium & phosphate
- **Blood Cell Formation** (*hematopoiesis*) – RBC & WBC forms within red marrow cavities of certain bones

What is Bone Made of

Bone consists of two quite different materials plus water collagen, the major organic fraction, which is About 40% of the weight of solid bone and 60% of its volume, and (bone mineral).

inorganic component of bone, which is about 60%of the weight of the bone and 40% of its volume.

The large percentage of calcium in bone. Since calcium has a much heavier nucleus than most elements of the body, it absorbs X-rays much better than the surrounding soft tissue. This is the reason X-rays show bones so well.

Obj.2
Why bones are shown by X-ray

Bone are made from calcium which has heaviest nucleus than any other element in the body, which absorb the energy of X-ray.

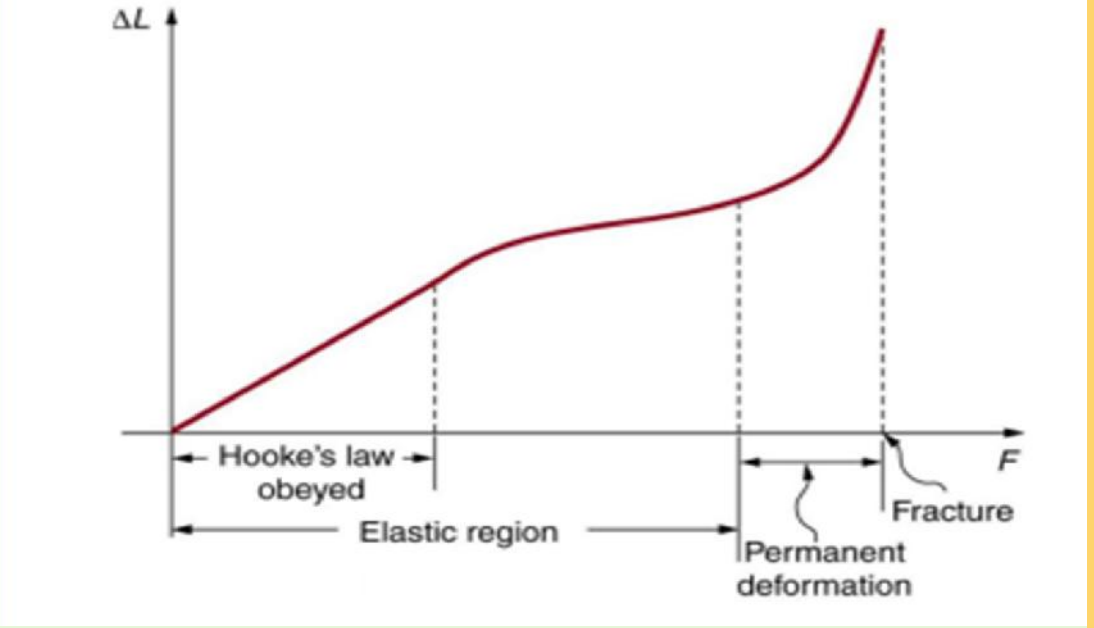
The large area of exposed bone mineral crystal permits the bones to interact rapidly with chemicals in the blood and other body fluids.

✓ **Also certain foreign bodies like stones present in the kidney can be shown by X-ray because it contain calcium in its structure.**

Using X-Rays scattering indicates that bone mineral crystals are rod shaped of diameter 20–70 Aº and length 50–100 Aº.

How strong are your bones?

- **when a piece of bone is placed under increasing tension, it's strain increase linearly at first (Hook's law) and then more rapidly just before it breaks.**



All materials change in length when placed under tension or compression. When a sample of fresh bone placed in a special instrument for measuring the elongation under tension, a curve similar is obtained.

The strain ΔL/L increases linearly at first, indicating that is proportional to the stress (F/A) Hooks law.

As the force increases the length increases more rapidly, and the bone breaks at stress of about 120 N/mm2. The ratio of stress to strain in the initial linear portion is Young's modulus.

$$Y = (L\ F) / (A\ \Delta L)$$

Example:

Assume a leg has 1.2m shaft of bone with an average cross-sectional area of $3 \times 10^{-4}\ m^2$
What is amount of shortening when all of the body weight of 700 N is supported on this leg.

Sol.

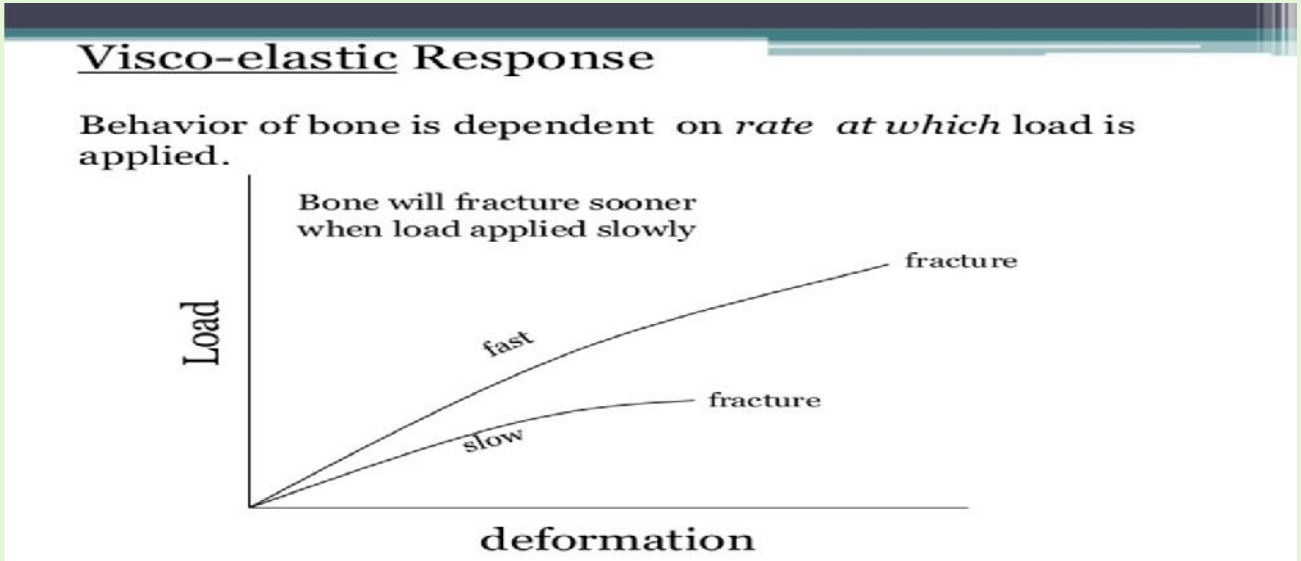
$$\Delta L = \frac{LF}{AY} = \frac{(1.2m)(7 \times 10^2 N)}{(3 \times 10^{-4})(1.8 \times 10^{10} N/m^2)} = 1.5 \times 10^{-4}\ m = 0.15\ mm$$

- **The good lubricating properties of synovial fluid are thought to be due to the presence hyaluronic acid and mucopolysaccharide of molecular weight 500000 which deform under load.**

- **The viscosity of synovial fluid decreases under large sheer stress found in the joint**

In running the force on the hip bone when the heel strikes the ground may before times the body's weight.

In normal walking the force on the hip are about twice the body's weight. Exceeding maximum compressive strength of bone is not as dangerous as the same force applied over a long period of time.
This property called *viscoelasticity.*



Definition of Piezoelectricity

Electricity or electric polarity due to pressure especially in a crystalline substance (such as quartz)

When bone is bent it generates an electrical charges on its surfaces called piezoelectricity, may act as physical stimulus for bone growth and repair.

Experiments with animal bone fractures have shown that bone heals faster if an electrical potential is applied across the broken bone.

Obj.3
Measurement of Bone Minerals in the Body

The idea of using an x-ray image to measure the amount of bone mineral, the major problems of using an ordinary X-ray are:-

(1) the usual x-ray beam has many different energies, and the absorption of x-rays by calcium varies rapidly with energy in this range of energies.

(2) The relatively large beam contains much scattered when it reaches the film.

(3) The film is a poor detector for making quantitative measurements since it is nonlinear with respect to both the amount and the energy of the X-rays.

The three problems of X-Ray use are eliminated here by using:

- ✓ Mono energetic X-Ray or gamma ray source.
- ✓ A narrow beam to minimize scatter.
- ✓ A scintillation detector that detects all photons.

Dual Photon a absorbiometric technique (Dexa scan).

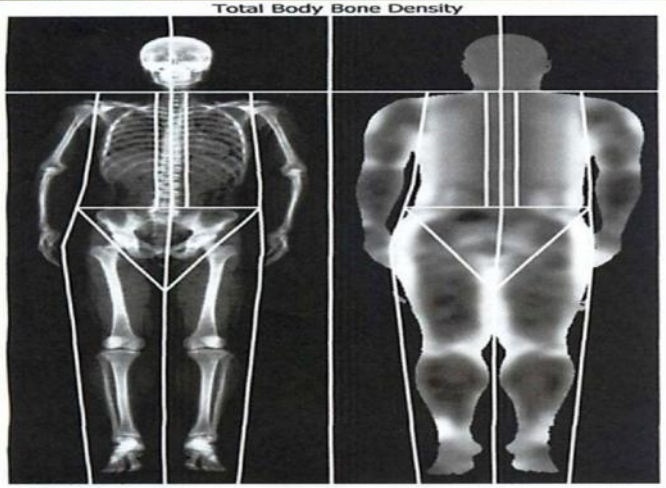
It is a modern clinical bone scanner that uses photon absorption technique.

DEXA SCAN

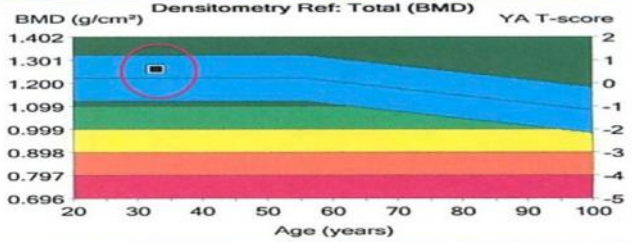
University of California Los Angeles School of Nursing
900 Weyburn Place N., Warren Hall Room 23-153
Los Angeles, CA 90095

Patient:	[redacted]	**Facility ID:**			
Birth Date:		**Referring Physician:**			
Height / Weight:		**Measured:**	11/23/2013	11:19:45 AM	(13.60)
Sex / Ethnic:		**Analyzed:**	11/23/2013	11:19:50 AM	(13.60)

Total Body Bone Density



Densitometry Ref: Total (BMD)



Region	BMD [1] (g/cm²)	Young-Adult [2] T-score	Age-Matched [3] Z-score
Head	2.002	-	-
Arms	1.064	-	-
Legs	1.333	-	-
Trunk	1.075	-	-
Ribs	0.998	-	-
Pelvis	1.076	-	-
Spine	1.199	-	-
Total	1.264	0.6	0.4

COMMENTS:

Image not for diagnosis

Printed: 11/23/2013 11:21:10 AM (13.60)100:0.19:153.85:15.6 0.00:-1.00
2.40x3.04 13.0:%Fat=27.4%
0.00:0.00 0.00:0.00
Filename: 2fdqwm4any.meb
Scan Mode: Standard 3.0 µGy

1 - Statistically 68% of repeat scans fall within 1SD (± 0.010 g/cm² for Total Body Total)
2 - USA (Combined NHANES (ages 20-30) / Lunar (ages 20-40)) Total Body Reference Population (v112)
3 - Matched for Age, Weight (males 25-100 kg), Ethnic

GE Healthcare

Lunar iDXA
1RME+200446

Since bone is living tissue, it undergoes changes throughout life.

A continuous process destroying old bone and building new bone, called bone remodeling is slow work.

Bone remodeling is performed by specialized bone cells, the osteoclast that destroy the bone, and osteoblast build it, we have the equivalent of a new skeleton about every 7 years

- **When osteoclast activity faster than osteoblast especially in female after the age of 35 years, this lead to osteoporosis which results in spontaneous fractures, especially in the spine and hips.**

One osteoclast can destroy bone 100 times faster than one osteoblast can build new bone, as in other aspects of life.


Thank you