Medical Physics

Force on and in the body

Lecture One

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- Force on and in the body

Forces

Forces in the body

1-Gravitational force

2-Electrical force

3-Nuclear force

Forces on the body

1- Static force

2-Dynamic force

3-Frictional force

Forces in the body

1-Gravitational forces.

Newton formulated the law or universal gravitation. **This law states that there is a force of attraction between any two objects; our weight is due to the attraction between the earth and our bodies.**

W = gm

W: the weight (N, dyne). g: acceleration due to gravity (cm/sec^2 or m/sec^2), m: the mass (g, kg)

Medical effects of gravitational force

1. One of the important medical effects of gravitational force is the formation of varicose veins in the legs.
2. Medical effects of gravitational force on the skeleton (On the bones.

2-Electrical forces.

This force more complicated than gravity since it involves attractive and repulsive forces between static electrical charges as well as magnetic force produced by moving electrical charges (electrical current) .

Biological examples of electrical forces

1. Control and action of our muscles is primarily electrical.
2. Electric eels and some other marine animals.

3-Nuclear forces.

Its acts as the force to hold the nucleus together against the repulsive fare produced by the protons on each other.

Forces on the body

1-Statics: when objects are stationary, (static) they are in a state of equilibrium.

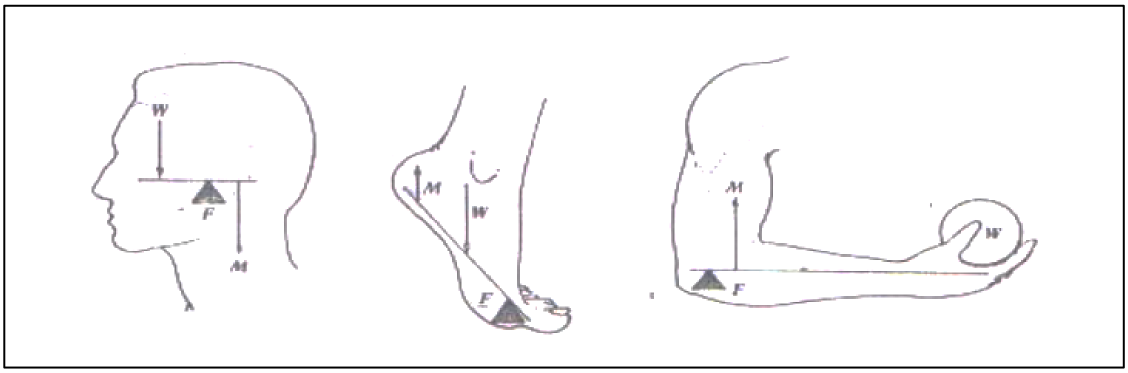
The sum of the forces in any direction is equal to zero, and the sum of the torques about any axis is zero.

Many of the muscle and bone systems act as levers, which are classified to:

a-First class levers: They are least common in the body. The fulcrum paint (F) is between the muscle forces (M) and the weight (W), for example the head.

b-**Second class levers**: They are found more than first class levers, Weight (W) is between the fulcrum point (F) and muscle forces (M), for example standing on the toes.

c- **Third class levers**: They are most common in the body. Muscle forces (M) is between fulcrum points (F) and weight (W). For example, the arm in the elbow joint.



2-**Dynamic**: Let us examine forces, which are important when the body is moving and hitting another body.

The Newton's second law, force equals mass times acceleration.

F= ma

Newton said" force equals the change of momentum Δ(mv) over a short interval

Of time Δt $F = \frac{\Delta(mv)}{\Delta t}$

Example 1: A (60 kg) person walking at (1m/sec) bumps into a wall and stops in a distance of (2.5 cm) in an about (0.05 sec). What is the force developed on impact?

Sol.

$\Delta(mv) = (60\ kg)(1 m/sec) - (60\ kg)(0\ m/sec) = 60\ kg\ m/sec$

$F = \frac{\Delta(mv)}{\Delta t} = \frac{60\ kg\ m/sec}{0.05\ sec} = 1200\ kg\ m/sec^2$ or 1200 N

Example 2: a- A person walking at (1 m/sec) hits his head on a steel beam Assume his head stops in (0.5 cm) in about 0.01 sec. If the mass of his head is (4kg). What is the force developed?

Sol.

$\Delta(mv) = (4\ kg)(1 m/sec) - (4\ kg)(0\ m/sec) = 4\ kg\ m/sec$

$F=\frac{\Delta(mv)}{\Delta t} = \frac{4\ kg\ m/sec}{0.01\ sec} = 400\ kg\ m/sec^2$ or 400 N

3-Frictional forces

Frictional and the energy loss due to friction appear everywhere in our everyday life.

Friction limits the efficiency of most machines such as electrical generators and automobiles.

On the other hand, we make use of friction in devices such as rubber tires and automobiles brakes.

The maximum force of friction **f** is usually describe by

$f = \mu N$

Where **N** is a normal force and **μ** is a coefficient of friction between the two surfaces.

The value of **μ** depends upon the two material in contact, and it is essentially independent of the surface area.

Physics of the skeleton

Function of the bones in the body

1) **Support**.

2) **Locomotion**: Bone joints permit movement of one bone with respect to another.

3) **Protection**: The *skull* protects the brain and several of the most important sensory organs (eyes, and ears), the *ribs* protect heart and lungs, the *spinal column* protects spinal cord.

4) **Storage of chemicals**: - bones acts as a chemical bank for storing elements for future use by the body.

5) **Nourishment**: Teeth are specialized bones that can cut food by incisors, tear it by canines will, grind it by molars, and thus serve in providing nourishment for the body.

6) **Sound transmission**: The smallest bones of the body are ossicles in the middle ear the ossicles acts as levers it's provide an impedance matching system for converting sound vibrations in air to sound vibrations in fluids.

Bone consists of two different materials plus water:

A- Collagen, the major organic fraction, which is about 40% of the weight of the solid bone and 60% of its volume.

B- Bone mineral, the so-called "inorganic" component of bone, which is about 60% of the weight of the bone and 40% of its volume.

Thus:

The bone = water + collagen (organic material) + bone mineral (inorganic material)

Mechanical properties of bone

1) Density

The density of compact bone is constant through life at about 1.9 g/cm^3. In old age the bone become more porous and disappears from the inside or surface.

2) Young's modulus of elasticity:

All materials change in length when placed under tension or compression.

The strain = $(\Delta L / L)$

The stress = (F/A)

As the force increases the length increases more rapidly, and the bone breaks at a stress of about **120 N/mm^2**.

The ratio of stress to strain in the initial linear portion is **young's modulus Y**.

That is:

$Y = \frac{LF}{A\Delta L}$ $\Delta L = \frac{LF}{AY}$