Al-Mustaqbal University

College of Technology and Health Sciences

Medical physics Department

Medical Physics

First Semester

3rd stage

Lesson 3

Forces on and in the body

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1. Introduction

Force, in general, controls all motion in the world. We are aware of forces on the body such as the force involved when we bump in to object. But we are unaware of important forces in the body, for example;

1. The muscular forces that cause the blood to circulate
2. The lungs to take in air
3. The electrical forces that trap a particular atom or molecule to a place in the body. For example; in the bones, calcium atom is part of bone minerals. Calcium will become part of the crystal if the electrical forces are great enough to trap it. It will stay in place until conditions changed and the electrical forces no longer hold it. This happen if the bone crystal is destroyed by osteoporosis (figure 1) and bone cancer.

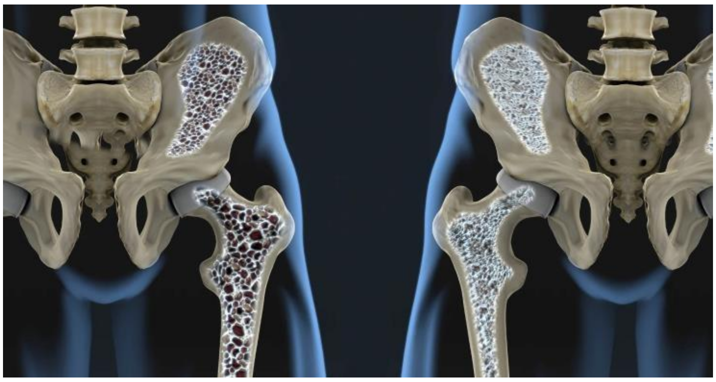

Figure 1. Osteoporosis.

2. Fundamental origins of force

1. Gravitational force
2. Electrical force
3. Nuclear force (Not discussed in this lesson)

Gravitational force

Newton formulated the law of gravitation. This law states that there is an attraction force between any two objects. Our weight is due to the attraction between the earth and our bodies. The gravitational force is very important to maintain healthy body. For example; bone minerals and blood vascular system need the gravity.

Electrical force

This force is more complicated than gravitational force since it involves attraction and repulsion between static electrical charges.

Our bodies are electrical machines and some examples of electrical forces in the bodies are:

1. The forces produced by muscles are caused by charge attraction or repulsion.
2. Cells in the body has electrical potential difference across the cell membrane because of the charge difference between inside and outside the cell.

3. Forces on the body

There are two problems involving forces on the body; ***statics***, where the body is in equilibrium and ***dynamic***, where the body is moving. Another force that could be found in both static and dynamic is that the ***friction*** force.

3.1 Static

When body is static, it is in a state of equilibrium. This means the sum of all forces acting on it equals zero. Most of the muscle and bone systems of the body act as levers. The law of levers can be summarized in figure 2.

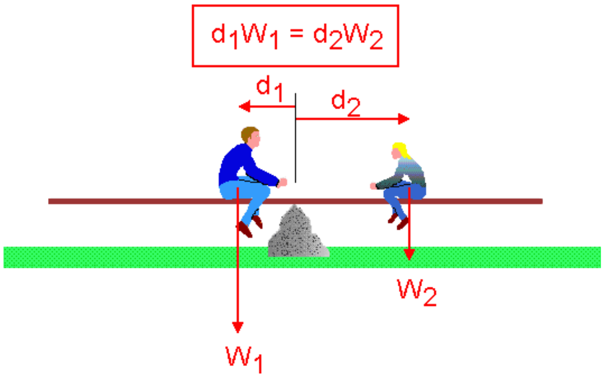

Figure 2. The general law of levers

Levers are classified as;

1. First lever system; where the fulcrum is between effort and load.
2. Second lever system; where the load is between fulcrum and effort.
3. Third lever system; where the effort is between fulcrum and load.

Third class lever is most common in the body, second class lever is the next and the first class is least common (figure 3).

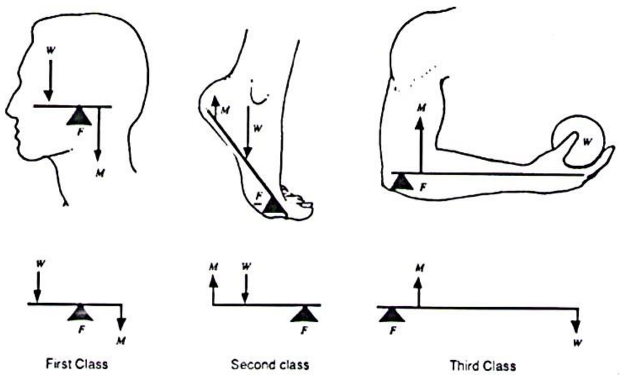

Figure 3. The three lever classes and schematic examples of each in the body. W is the force that could be the weight, F is the fulcrum point, and M is the muscle force.

Biceps muscle problem:

The biceps muscle acting to support a weight W in the hand (figure 4). The weight of the hand and arm are neglected in this example.

From the law of levers:

$d_1W_1=d_2W_2$ or; Torque1= Torque2

from the figure;

4M = 30W So,

M = 7.5 W.

That means the muscle force of 7.5 times the weight is needed to support it. For 100 N weight, the force needed by biceps muscle is 750 N

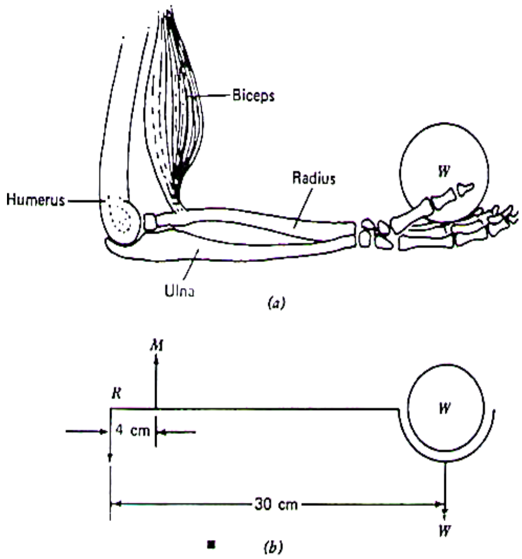

Figure 4. The forearm. (a) The muscle and bone system. (b) The forces and dimensions.

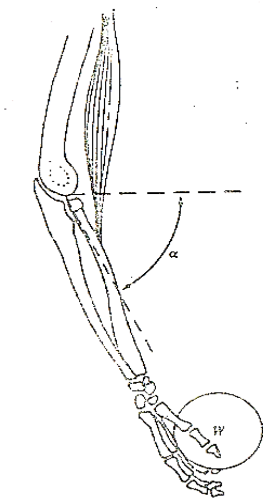

Figure 5. The forearm at angle α

Let us now consider the muscle force needed as the arm changes its angle as shown in figure 5.

The length of the biceps changes with the angle. In general, each muscle has minimum length to which it can be contracted and maximum length to which it can be stretched and still function.

At these two extremes the force of the muscle is zero. At some point in between, the muscle can produce its maximum force.

Lower back problem:

An often abused part of the body is the lumber (lower back) region, shown in figure 6.

The calculated force at fifth lumber vertebra (L5) with the body tipped forward at 60^o with a weight of 225 N (23Kg) in the hands can approach 3800 N (387.5 Kg).

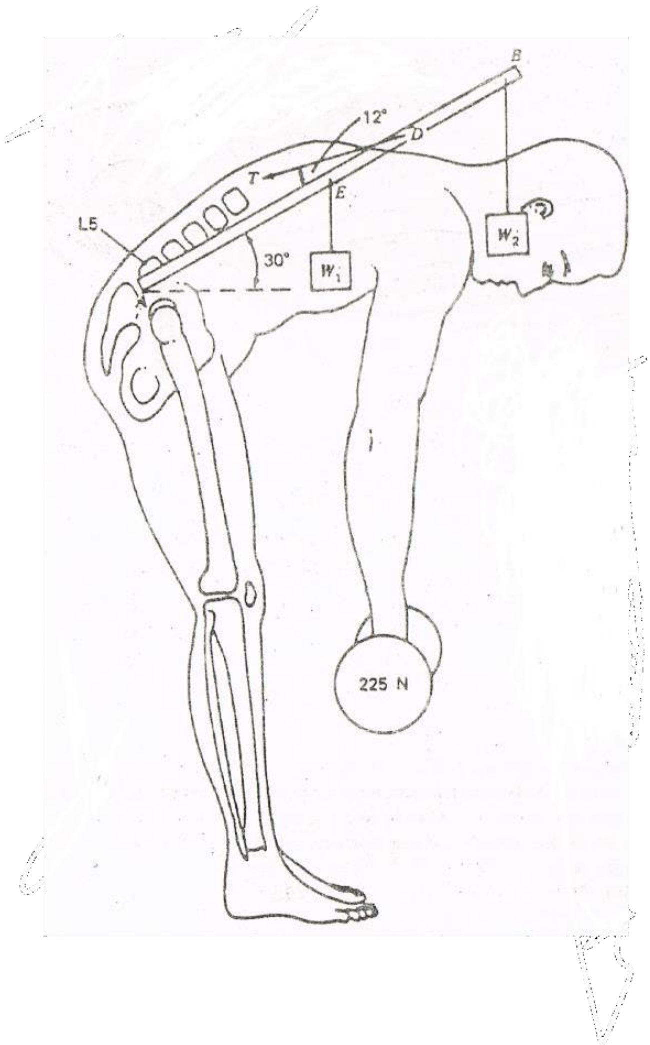

Figure 6. Lifting a weight

3.2 Frictional forces

Although some frictional forces are limiting the efficiency of most machines and joints in human body, they are so important for walking, driving a car, standing and every activity that we don't want to be slipped over when we do it.

When a person is walking, the force is transmitted from the foot to the ground (Figure 7). This force is divided into two components; vertical one, the weight (W) and horizontal one, the ***friction*** (*f*) which can be written as:

$$f = \mu W$$

Where μ is the friction coefficient and depends on the two materials in contact. Table 1 represents values of μ for some materials.

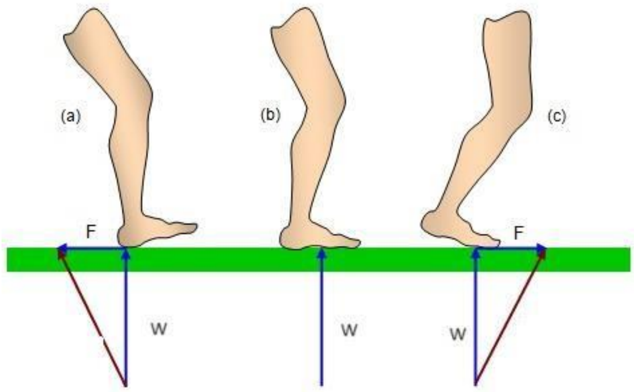

Figure 7. Normal walking

Table 1. Materials and friction

Material	**μ (Static friction)**
Steel on steel	0.15
Rubber tire on dry concrete road	1
Rubber tire on wet concrete road	0.7
Steel on ice	0.03
Between tendons and sheath	0.013
Lubricated bone joint	0.003

Friction in normal walking……

The horizontal force needed when heel strikes the ground is measured to be 0.15W, where W is person's weight. This how large the frictional force must be to prevent slipping.

For a person wearing rubber shoes and walking on concrete; the frictional force will be;

$$f = \mu W$$

From table 1;

$$f = 1W$$

That means; frictional force is a way larger than the horizontal force needed (0.15W).

On the other hand, when person on ice or wet surface where μ is less than 0.15, the foot slips and results in broken bones sometimes.

Friction inside our body……

- The synovial fluid in the joint is involved in lubrication. If disease of the joint exists, the friction become very large.
- The saliva in mouth is a lubricant. If we swallow a dry food, it's quite painful.
- All our inside organs are lubricated with suitable lubricant such as; Lungs and heart are moving and there is a suitable fluid to prevent friction.

Forces on and in the body will continue in the next lesson……

Exercises

1 **Calcium atom is part of the bone crystal and it stays in its place because.**

(a) The nuclear force is enough to hold it

(b) The gravitational force is enough to hold it

(c) The frictional force is enough to hold it

(d) The electrical force is enough to hold it

(e) The mechanical force is enough to hold it

2 **The general law of levers could be written as;**

(a) $d_1W_1 = d_2W_2$

(b) $d = W$

(c) $d_1W_2 = d_2W_1$

(d) $d_1W_2 + d_2W_1 + d_3W_3 = 0$

(e) $dW = 0$

3 **The class of levers where the effort is between fulcrum and load is;**

(a) First lever system

(b) First and second lever system

(c) Second lever system

(d) Second and third lever system

(e) Third lever system

4 **The force needed in the biceps muscle to support a weight (W) should be ;**

(a) M = 7.5 W

(b) M = 1 W

(c) M = 9.5 W

(d) M = 0.5 W

(e) M = W

5 **The synovial fluid in the joint is involved in lubrication. If disease of the joint exists,**

(a) Friction become very small.

(b) Friction become very large.

(c) Friction is not affected.

(d) Friction become zero.

(e) None of them.