University of Al-Mustaqbal
College of Science
Department of Medical Physics

BIOPHYSICS

first stage

(Torques And Levers In Human Body)

Lecture Three

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Introduction:

Biophysics is a branch of science that studies the physical phenomena in living organisms. It deals with understanding how the principles of physics apply to biological processes. In this lecture, we will focus on three fundamental concepts in physics that play a significant role in biology: **Force**, **Energy**, and **Work**.

1. Force:

Force is a factor that causes a change in the motion of an object. In living organisms, force is responsible for various biological activities, such as muscle movement, blood flow within blood vessels, and cellular processes. Force is measured in **Newtons (N)** and can be calculated using the equation:

$$F=ma$$

Where:

- F is the force.
- m is the mass.
- a is the acceleration.

Types of Force in Biology:

- **Muscle Force**: Generated from the contraction of muscle fibers.
- **Frictional Force**: When objects interact with each other in a biological system.
- **Gravitational Force**: Affects the movement of living organisms.

2. Energy:

Energy is the ability to do work and is fundamental to all biological processes. There are two main types of energy:

- **Kinetic Energy**: The energy associated with motion. For example, the movement of muscle tissues during exercise.
- **Potential Energy**: The stored energy in an object. Like the energy stored in the chemical bonds of food molecules.

In living organisms, chemical energy from food is converted into kinetic and thermal energy during biological activities.

Energy is measured in **Joules (J)**, and can be calculated using the equation:

$$E= F\times d$$

Where:

- E is the energy.
- F is the applied force.
- d is the distance the object is moved.

3. Work:

Work is the transfer of energy that results from the application of force on an object that moves. In biological systems, work is the mechanism through which energy is transferred within living organisms.

When a force acts on an object and the object moves in the direction of the force, work is done. Work can be calculated using the equation:

$$W = F \times d \times \cos(\theta)$$

Where:

- W is the work done.
- F is the applied force.
- d is the distance moved by the object.
- θ\theta is the angle between the force direction and the direction of motion.

Applications in Biological Life:

- **Muscles and Movement**: During exercise or any activity requiring movement, muscles apply forces on bones, performing work and converting chemical energy into kinetic energy.
- **Circulatory System**: The heart generates force to pump blood through blood vessels, helping to transport oxygen and nutrients to tissues.
- **Cellular Systems**: Within cells, energy is used for processes such as ion transport across cell membranes, muscle contraction, and cell division.

Principles of Body Mechanics

- Principles of body mechanics:

• The wider the base of support, the more stable the body. The lower the center of gravity, the more stable the body. The balance of the object is maintained as long as it is

The gravity line passes through its supporting base.

• Dividing balanced activity between arms and legs reduces the risk of back injury.

• Maintaining good body mechanics reduces muscle fatigue.

•LEVER

Fulcrum (f) The bar may be straight. • A lever is an example of a simple machine. It is a rigid bar that moves around a fixed axis called

In addition to the fulcrum, the lever consists of two forces:

• potential E and resistance R Machine law Rdr=Ede A force FE is applied to one end of the beam and the load force FL is balanced. The mechanical advantage (MA) of the lever is defined as FE/FL=MA

- levers are classified into three categories: • According to

• **First-class levers**: In this class of lever, the fulcrum is located somewhere between the effort and the resistance (Figure 4.4). Like scissors in a body.The human first-degree lever is represented by the triceps brachii muscles.

• **Second class levers**: In this class of lever, the resistance lies between the fulcrum and the force (Figure 4.5). The hand cart and the oxygen cylinder are considered

Examples of second degree lever.

• Third-degree levers: In a third-degree lever, the effort lies between the resistance and the point (Figure 4.6). The forceps and the action of the biceps

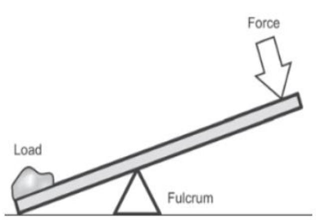


Fig. 4.4: First class lever

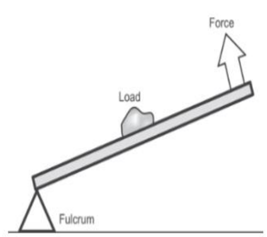


Fig. 4.5: Second class lever

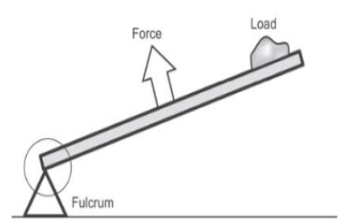


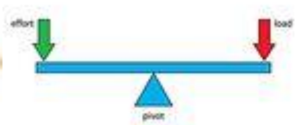
Fig. 4.6: Third class lever

Mechanical advantage

Muscles and bones act together to form levers.
A lever is a rigid rod (usually a length of bone) that turns about a pivot (usually a joint). Levers can be used so that a small force can move a much bigger force. This is called mechanical advantage.

There are four parts to a lever – lever arm, pivot, effort and load. In our bodies:
bones act as lever arms
joints act as pivots
muscles provide the effort forces to move loads
loads are the body parts that are being moved

Levers can also be used to magnify movement, for example, when kicking a ball, small contractions of leg muscles produce a much larger movement at the end of the leg.

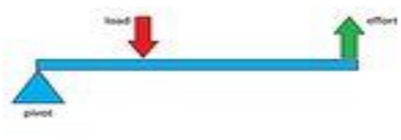


Types of Levers

Class 1 lever – nod your head

The pivot is the place where your skull meets the top of your spine. Your skull is the lever arm and the neck muscles at the back of the skull provide the force (effort) to lift your head up against the weight of the head (load). When the neck muscles relax, your head nods forward.

Class 2 lever – stand on tip toes

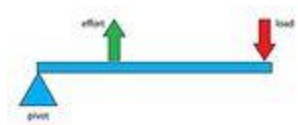


Tip-toe

The pivot is at your toe joints and your foot acts as a lever arm. Your calf muscles and Achilles tendon provide the effort when the calf muscle contracts. The load is your body weight and is lifted by the effort.

The load is between the pivot and the effort (like a wheelbarrow). The effort force needed is less than the load force, so there is a mechanical advantage. This muscular movement at the back of your legs allows you to move your whole body a small distance.

Class 3 lever – bend your arm

Bent arm

The pivot is at the elbow and the forearm acts as the lever arm. The biceps muscle provides the effort (force) and bends the forearm against the weight of the forearm and any weight that the hand might be holding.
The load is further away from the pivot than the effort. There is no mechanical advantage because the effort is greater than the load. However this disadvantage is compensated with a larger movement – a small contraction of the biceps produces a large movement of the forearm. This type of lever system also gives us the advantage of a much greater speed of movement.

What is torque?

In the examples above, the effort and load forces have acted in opposite rotation directions to each other. If a load tries to turn the lever clockwise, the effort tries to turn the lever anticlockwise. Forces acting on a lever also have different effects depending how far they are away from the pivot. For example when pushing a door open it is easier to make the door move if you push at the door handle rather than near to the hinge (pivot). Pushing on the door produces a turning effect, which causes rotation. This turning effect is called torque (or leverage).

You can increase the amount of torque by increasing the size of the force or increasing the distance that the force acts from the pivot. That's why the door handle is far away from the hinge.

Hamstring

Forces from our muscles produce torques about our joints in clockwise and anti-clockwise directions. If the torques are equal and opposite, the lever will not rotate. If they are unequal, the lever will rotate in the direction of the greater torque.
In this diagram, the load and weight of the lower leg produce a clockwise torque about the knee. The lower leg will rotate in a clockwise direction.
If the hamstring muscle at the back of the upper leg contracts with a strong force, it produces an anticlockwise torque that holds the leg up.

Lifting heavy weights

In this diagram, lifting the weight like the person on the left produces a greater torque about the lower spine (pivot) – the lifting force is at a greater perpendicular distance to the pivot. The back muscles must exert a huge force to provide a torque that balances the torque from the weight being lifted.
It is important to lift a heavy weight close to your body to reduce the torque produced around your lower spine