Chapter 1

Basic Physics and Mechanical Principles in Exercise Therapy

Learning Objectives

In this chapter, you shall learn about:

1. Definition of various physics and biomechanical principles used in physiotherapy.
2. Application of these principles in various physiotherapeutic interventions in exercise therapy.
3. Understand the biomechanical and physical principles for prescribing exercises.

AXIS AND PLANES

Human movements are complex and in order to describe the human movements a three dimension based description is given. The movements are described in terms of "axis and planes" (Fig. 1.1).

Axis: An axis is an imaginary straight line around which the movement occurs. It is the line along which an object, in this regard, a joint rotates. The movement at a joint occurs in a plane about an axis.

There are three axes of rotation

1. Sagittal axis
2. Frontal axis
3. Vertical axis

Sagittal axis: The sagittal axis is an imaginary line which passes horizontally from posterior to anterior and lies parallel to sagittal suture of the skull. Always A movement at this axis occur in frontal plane.

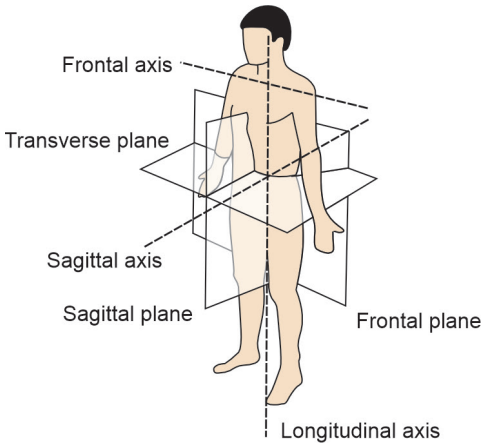

Fig. 1.1: Axes and planes

Frontal axis: The frontal axis is an imaginary line which passes from left to right side of the body and lies parallel to the frontal suture of the skull. It is also called as transverse axis. Always movement about frontal axis occurs in a sagittal plane.

Vertical axis: The vertical axis is an imaginary line that passes vertically from inferior to superior aspect of the body and is parallel to line of gravity. Always the movement about this axis occurs in a horizontal plane.

Planes: A plane is a surface along which a movement takes place and lies at right angles to axis.

There are three planes of motion that pass through the human body:

1. The sagittal plane
2. The frontal plane
3. The transverse plane

Sagittal plane: Also called as vertical plane. It divides the body into two equal halves into right and left and lies vertically. Movements in this plane include forward and backward motions such as nodding the head. The motions in sagittal plane occurs along coronal axis.

Frontal plane: Also called as coronal plane. It divides body into anterior and posterior halves and lies vertically movements in this plane occur around an anteroposterior axis.

Horizontal plane: Also called as transverse plane. This plane divides the body into superior and inferior halves and lies horizontally. Movements in this plane occurs parallel to the ground. Because of this, the movement is not affected by the gravity and are termed as gravity eliminated movements.

Importance of Knowledge of Planes and Axis in Exercise Therapy

Weightlifting, lifting and even body weight exercises are performed entirely within one plane.

In functional activities of life and sports , the movements occur n triplane, i.e. occurs in all 3 planes.

The three planes of motion plays a very important role and act as a vital tool for application and progression of resistance exercises, load exercises, speed, range of motion exercises.

Weak muscles which are unable to produce movement against gravity can often be exercised to improve power in the Horizontal plane.

KINEMATICS

It is the branch of biomechanics concerned with the study of movement from a geometrical point of view. In this the movement is described regardless of forces producing it.

Kinematics describe the movement under the following headings:

1. Type of motion
2. Location of motion
3. Direction of motion
4. Magnitude of motion

Type of Motion

Rotatory motion: If an object moves around a fixed axis in a curved path with each point on the object or segment moves through the same angle at same distance, then it is describes as rotatory motion (Fig. 1.2).

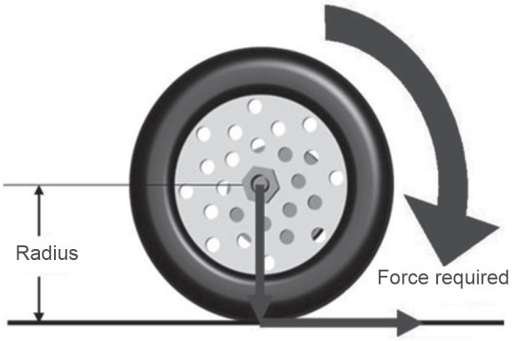

Fig. 1.2: Rotatory motion

Translatory motion: If an object or segment moves in a straight line such that each point of an object or segment moves through the same distance, at the same time in parallel paths, then the motion is called as translatory motion (Fig. 1.3).

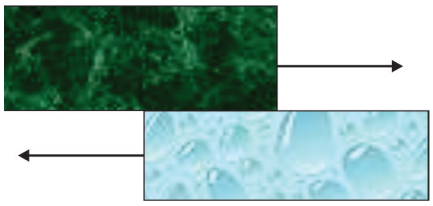

Fig. 1.3: Translatory motion

Curvilinear motion: This movement is a combination of rotatory and translator motion. It is the most common form of motions produced in human joints (Fig. 1.4).

General plane motion: In this the object is segmented and free to move in any direction.

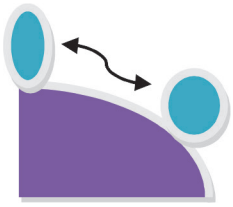

Fig. 1.4: Curvilinear motion

Location of Motion

It describes the movement at a joint in terms of axis and planes.

Direction of Motion

Movement may occur in clockwise or anticlock wise direction.

Magnitude of Motion

Describes the movement in terms of degrees. Usually a goniometer is used for measurement of magnitude of movement at joints and is termed as range of motion.

KINETICS

It is the branch of biomechanics concerned with the forces that produce the motion or maintain equilibrium.

FORCE

It is the capacity to alter the state of rest of a body or its uniform motion in a straight line.

Types of Forces

Biomechanically there are two types of forces:

1. External forces
2. Internal forces

External forces are the forces exerting on the body from outside, e.g. gravity.
Internal forces are forces being exerted from inside the body, e.g. pull of the muscles.

Composition of Forces

1. Direction of force
2. Magnitude of force
3. Point of application of force

In Fig. 1.5, the "direction of force" is represented by an arrow, magnitude by the length of the arrow and the tail of the arrow represents the point of application.

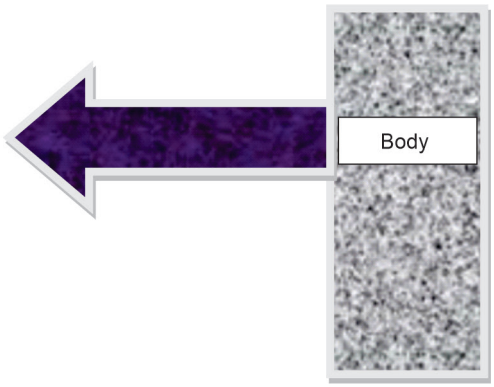

Fig. 1.5: Composition of forces

FIXATION AND STABILIZATION OF FORCES

- Fixation describes a state of immobility
- Stabilization describes relative immobility
- Fixation is a general procedure by which movement at a joint is prevented, e.g. to maintain a posture

Methods of Fixation and Stabilization in Physiotherapy

- Traction
- Weight bags
- Splintage
- Straps

GRAVITY

Gravity is the force by which all the bodies are attracted towards the earth. The force of gravity continuously acts upon the human body.

Center of gravity: It is the point where the force of gravity effectively acts on a body.

In humans the center of gravity lies at second sacral vertebra level (Fig. 1.6).

Fig. 1.6: Center of gravity (COG)

Line of gravity: The line of the gravity is a vertical line that passes through the center of gravity.

In humans it passes through the mid cervical and mid lumbar vertebra and in front of thoracic vertebra (Fig. 1.7).

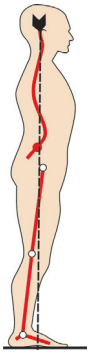

Fig. 1.7: Line of gravity

Base of support: It is the area by which a rigid body is being supported and plays a very important role in equilibrium.

Equilibrium: When all the forces acting on a body are perfectly balanced, the body is said to be in equilibrium.

There are three states of equilibrium

- Stable equilibrium
- Unstable equilibrium
- Neutral equilibrium

Fig. 1.8: Stable equilibrium

Stable equilibrium: If the forces acting upon a body at rest can restore its original position after it has been displaced is called stable equilibrium, e.g. sitting (Fig. 1.8).

Unstable equilibrium: If the forces acting upon a body increase the initial displacement then the body is in unstable equilibrium, e.g. standing (Fig. 1.9).

Fig. 1.9: Unstable equilibrium

Neutral equilibrium: If the height and position of COG of a body remains constant even after displacement, then the body is said to be in neutral equilibrium, e.g. lying position (Fig. 1.10).

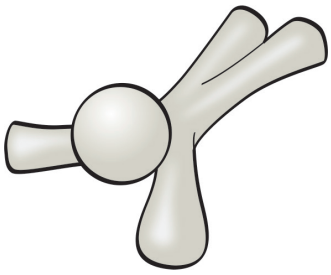

Fig. 1.10: Neutral equilibrium

PULLEYS IN PHYSIOTHERAPY

A pulley is a device which changes the direction of force without actually changing the magnitude of the force (Fig. 1.11).

Anatomical pulleys: They change the direction of pull of a muscle to increase the efficiency, e.g. "Patella" acts as an anatomical pulley for quadriceps muscle at knee complex (Fig. 1.12).

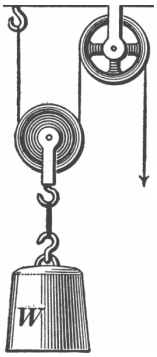

Fig. 1.11: Pulley device

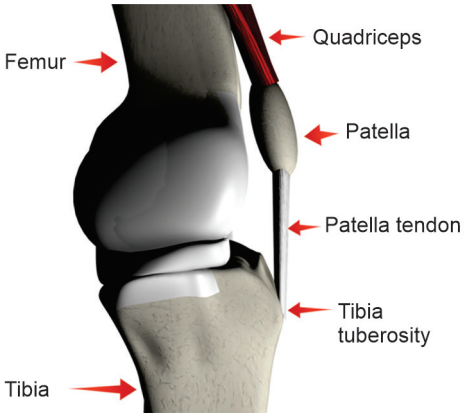

Fig. 1.12: Anatomical pulleys

A pulley is used in physiotherapy as a grooved wheel which can be rotated about a fixed axis by a rope passing through it (Fig. 1.13).

There are two types of pulleys used in physiotherapy:

- Fixed pulley
- Movable pulley

Fig. 1.13: Pulley used in physiotherapy

SPRINGS IN PHYSIOTHERAPY

These are extensible spiral coils of metal wires which are either used for assisting or resisting a movement (Fig. 1.14).

The extensibility of a spring is defined as the property of elongation in the direction of long axis and recoils after the force is removed.

Fig. 1.14: Spiral coils of metal

Springs are used in physiotherapy department for (Fig. 1.15):

1. Various resistance and assistance exercises
2. Stretching and maintaining position
3. Suspension therapy

Springs can be used either in series or in parallel.

Elasticity: It is the property of a body to regain its original form after the distortion force is released, e.g. muscles.

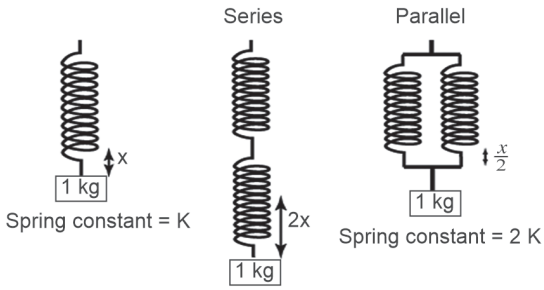

Fig. 1.15: Uses of spring in physiotherapy

Hooke's law: Within the elastic limits, the strain is directly proportional to the stress producing it.

Springs, rubber, elastic all possess elastic property.

LEVERS IN EXERCISE THERAPY

A lever is a rigid bar capable of moving about a fixed point called fulcrum. The movements in the human body are produced by a series of levers working together. The coordinated action of these levers results in smooth purposeful and accurate movements. Some levers help in stabilization and some help in dynamic motion.

Each lever moves on a fixed point called fulcrum with weight and effort on either side. An effort or exertion is applied to cause the movement against resistance or weigh which is known as motive force. A resistance force is that that opposes a motive force which is usually weight. The effort is the muscle force.

The perpendicular distance between weight and fulcrum is called weight arm. The perpendicular distance between effort and fulcrum is known as effort arm.

There are three orders of levers classified on the basis of position of fulcrum, effort and weight.

First class levers

In these type of levers, the fulcrum is between weight and effort. The elbow extension by triceps contraction is a good example. The characteristics of these levers is a balanced movement as the fulcrum is in between effort and weight, speed and good range of motion and force.

Second class levers

In these type of levers, the weight is in between fulcrum and effort. The plantar flexion of foot is a good example. The characteristic of these type of levers are produces greater forces with less effort.

Third order lever

In these type of levers, the effort is between the fulcrum and weight. Most of the levers in body are third class levers. Biceps and brachialis action at elbow are good examples. The characteristics of these levers are they produce speed and good range of motion.

LEVER ARM LENGTH

Effort arm: It is the distance between fulcrum and point of effort. It is denoted by EA.
Weight arm: It is the distance between fulcrum and point of application of resistance or weight. It is denoted by WA.

LEVERAGE IN EXERCISES

When one wants to increase the speed and range of motion, the resistance arm should be longer than the effort arm.

When one wants force a short resistance arm should be used.

MECHANICAL ADVANTAGE IN LEVERS

The ratio of weight to effort is known as mechanical advantage (MA).

MA = Weight/effort = weight arm/effort arm. For third order levers the mechanical advantage is less than one. Hence these levers attain greater range of motion. The disadvantage of these levers is that it requires larger efforts to hold smaller weights. For example, holding a weight in hand and doing elbow flexion in supination. The mechanical advantage of second order levers is greater than one. These levers move weight farther than the effort. The mechanical advantage of first order levers is equal to one. They require smaller effort to move larger loads.

MULTIPLE CHOICE QUESTIONS

1. Which of the following is not a sub structure of atom?

a. Proton
b. Electron
c. Neutron
d. Ion

Ans. d

2. Which law states, the strain is directly proportional to stress producing it?

a. Hooke's law
b. Starling's law
c. Boyle's law
d. Charles' law

Ans. a

3. Which of the following act as an anatomical pulley?

a. Femur
b. Tibia
c. Patella
d. Ulna

Ans. c

4. Which of the following is an example for stable equilibrium?

a. Sitting
b Standing
c. Lying down
d. Running

Ans. b

STATE TRUE OR FALSE

1. Standing is an example for neutral equilibrium. (T)

2. Springs can be used in series or parallel. (T)

3. **The less the base of support, the more the balance. (F)**
4. **Kinematics studies the forces causing a motion. (T)**
5. **Muscles show elastic property. (T)**

SHORT ESSAY QUESTIONS

1. **Define kinematics.**
2. **Define anatomical pulley.**
3. **How springs are used in physiotherapy.**