SNS COLLEGE OF PHYSIOTHERAPY

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DEPARTMENT OF PHYSIOTHERAPY- II YEAR

COURSE NAME- Bio-Mechanics

TOPIC- Introduction to Bio-mechanics

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Defining Biomechanics and Scope

Biomechanics explores the physical principles that must be considered to examine the internal and external forces that produce or control movements.

Focus: This introduction concentrates largely on **rigid body analysis**

Subsequent studies examine how forces affect **deformable connective tissues** and how **muscles generate and are affected by forces.**

The overall objective is to cover the key biomechanical principles necessary to understand individual joints and their interdependent functions in **posture and locomotion**

Kinematics

Definition: Kinematics includes the set of concepts that allows us to **describe the displacement (change in position over time) or motion of a segment**

Kinematics describes motion **without regard to the forces that cause that movement**

Five Kinematic Variables that Describe Motion:

1. **Type of Displacement** (motion)
2. **Location in Space** of the displacement
3. **Direction** of the displacement
4. **Magnitude** of the displacement
5. **Rate** of change in displacement (velocity) or rate of change of velocity (acceleration)

Types of Displacement

1. Translatory Motion (Linear Displacement): Occurs when all points on the object or segment move the **same distance, at the same time, in parallel paths**.

Example: Ideally, the tibia translates anteriorly during the anterior drawer test.

2. Rotary Motion (Angular Displacement): Movement of an object around a fixed axis.

3. General Motion: Most joint motions are a combination of rotation and translation, resulting in a **curvilinear path**.

Location, Direction, and Degrees of Freedom

Location in Space: Displacement is located using the **three-dimensional Cartesian coordinate system**.

Axes: **x-axis (Coronal axis)**, **y-axis (Vertical axis)**, and **z-axis (Anteroposterior or A-P axis)**.

Motion can occur **around** an axis (rotation) or **along** an axis (translation).

Degrees of Freedom (DOF): The potential options for movement of a segment.

An unconstrained segment has **six degrees of freedom** (three rotations and three translations).

Direction of Displacement: Described relative to the **anatomic planes** (sagittal, frontal, transverse) and their corresponding axes.

Example: Flexion and extension generally occur in the sagittal plane around a coronal axis.

Introduction to Forces (Kinetics)

Definition of Force: Simplistically, a **push or a pull exerted by one object or substance on another**.

Units of Force: Newton (N) in the SI system; **pound (lb)** in the US system.

Note: Mass units are the kilogram (kg) and slug, which are distinct from force units.

Internal Forces: Forces that act on body structures and arise from the body's own structures (e.g., muscle pull on bone, bone push on bone at a joint).

External Forces: Forces originating outside the body (e.g., gravity, weight of a boot, atmospheric pressure, push of a footplate)

Force Vectors and Gravity

Forces are represented by **vectors** that specify three characteristics: **magnitude** (length of arrow), **direction/orientation**, and **point of application**.

Primary Rules of Forces (Concept Cornerstone 1-1):

1. All forces on a segment must come from something that is contacting that segment.
2. Anything that contacts a segment must create a force on that segment.
3. Gravity can be considered to be “touching” all objects.

Force of Gravity: Always vertically **downward toward the center of the earth**.

The vector representing gravitational force is the **Line of Gravity (LoG)**. The LoG is attached to the **center of mass (CoM)** of the object

Center of Mass (CoM) and Stability

Center of Mass (CoM): The point where all the mass of an object is considered to be concentrated.

CoM of the Human Body: Lies approximately **anterior to the second sacral vertebra (S2)** when the body is considered a single rigid object in anatomic position.

The location of the CoM changes when segments are rearranged or when external mass (like a backpack or cast) is added.

Stability of an Object (Concept Cornerstone 1-4):

1. The **larger the base of support (BoS)**, the greater the stability.
2. The **closer the CoM is to the BoS**, the more stable the object.
3. An object cannot be stable unless its **Line of Gravity (LoG) is located within its BoS**

Introduction to Statics and Dynamics

Statics: The study of conditions under which objects **remain at rest**.

Dynamics: The study of conditions under which objects **move** (accelerate).

Newton's Law of Inertia (First Law/Law of Equilibrium): For an object to be in **equilibrium** (static or uniform motion), the sum of all the forces (ΣF) and the sum of all the torques (Στ) applied to that object must be **zero**.

Newton's Law of Acceleration (Second Law): If the sum of forces or torques acting on an object is **not zero** (Σ□=0 or Στ=0), the object cannot be in equilibrium and **must be accelerating**.

Newton's Law of Reaction (Third Law): For every action, there is an equal and opposite reaction

Translatory Motion in Linear and Concurrent Force Systems

Linear Force Systems: Forces have action lines that lie in the **same line** (co-linear) and same plane (coplanar).

Resultant: Determined by adding or subtracting forces based on direction (e.g., gravity pull downward + weight boot pull downward = distraction force).

Concurrent Force Systems: Vectors have action lines that **intersect** (act at the same point).

Resultant: Determined by vector addition through **composition** (e.g., using the parallelogram method).

Tensile Forces (Concept Cornerstone 1-7): Forces that pull on an object. They are always equal in magnitude, opposite in direction, and applied **parallel to the long axis** of the object.

Joint Forces: Compression and Distraction/Shear

Joint Distraction Forces (Concept Cornerstone 1-8): Forces that create **separation of joint surfaces**.

They are perpendicular to the joint surfaces and directed **away** from the segment's joint surface.

Joint Compression Forces (Concept Cornerstone 1-9): Forces that create **contact between joint surfaces**.

They are perpendicular to and directed **toward** the segment's joint surface.

Shear Force (*FS*): Any force (or component) that has an action line **parallel to contacting surfaces** (or tangential to curved surfaces).

Shear forces create or limit movement between surfaces.

Friction Force (*Fr*): Potentially exists when there is a contact force; it is always **parallel** to contacting surfaces and acts to oppose motion or attempted motion.

Kinetics: Rotary Motion and Torque

When a force is applied away from the center of mass of an object, it tends to produce **rotation**.

Torque (τ) is the strength of rotation produced by a force.

Torque Calculation: Torque is a product of the magnitude of the force (F) and the shortest perpendicular distance from the force's action line to the axis of rotation (**Moment Arm, MA**).

$\tau = F \times MA$

Unbalanced Torque ($\Sigma\tau = 0$): Causes **angular acceleration**.

Force Couple: Two forces (equal magnitude, opposite direction, parallel, applied at different points) that produce **pure rotary motion**.

Moment Arm and Force Components

Moment Arm (MA): The **perpendicular distance** between the force vector and the joint axis.

Torque Maximization (Concept Cornerstone 1-14): The potential to produce torque is **maximum** when the force is applied at 90◦ to the segment, maximizing the MA.

Force Components: A force (e.g., a muscle force, *FTOT*) can be mathematically resolved into two components perpendicular to one another:

1. **Perpendicular component (*Fy*):** Directed at 90◦ to the segment; primarily responsible for **Rotation (Torque)**.

2. **Parallel component (*Fx*):** Directed parallel to the long axis of the segment; responsible for **Translation** (either compression toward the joint or distraction away from the joint).

Lever Systems

A lever system involves an **axis (fulcrum)**, an **effort force (EF)**, and a **resistance force (RF)**.

Mechanical Advantage (MAd): The ratio of the effort arm (EA) to the resistance arm (RA).

MAd=EA÷RA

First-Class Lever: Axis is located between the EF and the RF (e.g., head balancing on the atlanto-occipital joint).

Second-Class Lever: Resistance is located between the Axis and the Effort. MAd is **always greater than one** (MAd>1), making it mechanically efficient.

Third-Class Lever: Effort is located between the Axis and the Resistance. MAd is **always less than one** (MAd<1). The majority of muscles in the human body work in this system, favoring speed and range of motion over force efficiency

Biomechanics: Integrating Joints and Muscles

Connective Tissue Properties (Chapter 2): Joint structures respond to stress and strain.

* Tension→Ligament/Tendon

* Compression→Cartilage/Bone

* **Load-Deformation:** Describes elasticity (returns to original shape) and plasticity (permanent deformation).

* **Viscoelasticity:** Connective tissues are time-dependent (e.g., **Creep**—length gradually increases under constant load).

Muscle Structure and Function (Chapter 3): Muscles provide **mobility and stability** functions.

* **Active Tension:** Produced by cross-bridge interaction (related to muscle length/length-tension relationship).

* **Types of Contraction:** Concentric (shortening/effort force), Eccentric (lengthening/resistance force), Isometric (static) [122, 123, 122f, 121].

Integrated Function: Human movement requires interdependence among muscular forces, gravitational forces, and **articular constraints** (ligaments, capsules, joint reaction forces) to achieve movement and maintain equilibrium.

Multiple choice questions

Question	Options
Q1. Which statement accurately defines Kinematics in Biomechanics?	A. The study of forces that cause angular acceleration. B. The description of displacement or motion of a segment, regardless of the forces causing it. C. The investigation of equilibrium conditions (statics and dynamics). D. The analysis of how forces affect deformable connective tissues.

Multiple choice questions

Question

Q2. According to Newton's Law of Inertia (First Law), which condition must be met for an object to be in a state of equilibrium (at rest or in uniform motion)?

Options

A. The sum of all forces (ΣF) must equal the mass times acceleration ($m \times a$).

B. The object must have a large base of support (BoS) and a low center of mass (CoM).

C. The sum of all forces (ΣF) and the sum of all torques ($\Sigma\tau$) applied to that object must be zero.

D. The object must be accelerating due to an unbalanced force.

Multiple choice questions

Question

Q3. When is the potential for a muscle force to produce torque (rotation) maximized?

Options

A. When the angle of application of the force is parallel to the long axis of the segment.

B. When the force is applied parallel to contacting surfaces (shear force).

C. When the force's action line passes through the center of rotation of the segment.

D. When the force is applied at 90∘ to its segment, maximizing the moment arm.

Multiple choice questions

Question

Q4. The majority of muscles in the human body operate in which class of lever system, prioritizing range of motion and speed over force efficiency?

Options

A. First-Class Lever, where the Axis (A) is between Effort (E) and Resistance (R).

B. Second-Class Lever, where the Resistance (R) is between Axis (A) and Effort (E).

C. Third-Class Lever, where the Effort (E) is between Axis (A) and Resistance (R).

D. Zero-Class Lever (Statics).

Multiple choice questions

Question

Q5. What is the primary function of Proteoglycans (PGs) in connective tissues like cartilage?

Options

A. To act as the main contractile units responsible for tensile strength.

B. To determine the shape and architecture of muscle fibers.

C. To attract water through attached Glycosaminoglycans (GAGs), creating osmotic swelling pressure.

D. To form the dense, non-deformable meshwork necessary for bone resistance to compression.

Multiple choice questions with answers

1. B. The description of displacement or motion of a segment, regardless of the forces causing it. Kinematics includes concepts describing the displacement or motion of a segment, but does so without considering the forces that cause that movement

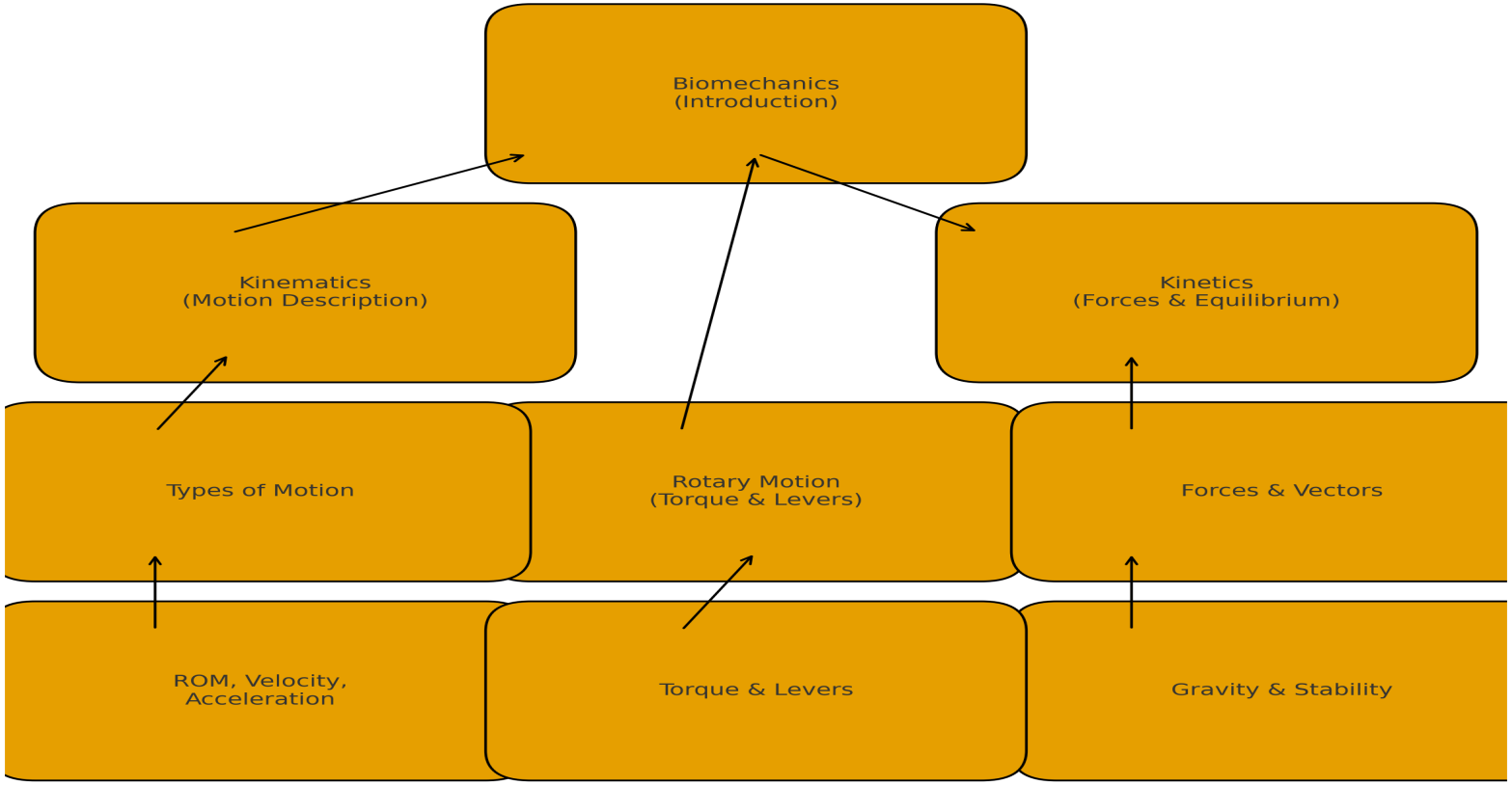
2. C. The sum of all forces (ΣF) and the sum of all torques (Στ) applied to that object must be zero. For an object to be in equilibrium (static or uniform motion), the sum of all the forces (ΣF) and the sum of all the torques (Στ) applied to that object must be zero

3. D. When the force is applied at to its segment, maximizing the moment arm. The potential to produce torque is maximum when the force is applied at ∘ to the segment, because this position maximizes the moment arm (MA).

4. C. Third-Class Lever, where the Effort (E) is between Axis (A) and Resistance (R). The majority of muscles in the human body work in a Third-Class Lever system, where the mechanical advantage (MAd) is always less than one.

5. C. To attract water through attached Glycosaminoglycans (GAGs), creating osmotic swelling pressure. Proteoglycans attract water through their attached GAGs. Aggrecan, a PG found in cartilage, creates osmotic swelling pressure by attracting water. Tissues subjected to compression, like discs, typically contain larger amounts of chondroitin sulfate and keratan sulfate.

SUMMARY


Biomechanics
(Introduction)
Kinematics
(Motion Description)
Kinetics
(Forces & Equilibrium)
Types of Motion
Rotary Motion
(Torque & Levers)
Forces & Vectors
ROM, Velocity,
Acceleration
Torque & Levers
Gravity & Stability

THANK YOU