Basic Biomechanics

…the body as a living machine for locomotion…

What is Kinesiology?

Kinesis: "to move"
-ology: "to study:
The study of movement

* What the heck does that mean?

Why do we need Kinesiology?

As health professionals, we must have expert knowledge of all muscle groups in the body.
There are ____ skeletal muscles in the human body

* With that knowledge, we then know how to strengthen, repair, improve, and maintain all body parts
  * Not only the how and what, but the WHY

* If we understand the forces acting on the human body, we can manipulate those forces in treatment procedures so that human performance may be improved and further injury may be prevented
Biomechanics

Biomechanics: the study of the mechanics as it relates to the functional and anatomical analysis of the human body.

- **Statics**: involves all forces acting on the body being in balance, resulting in the body being in equilibrium.
- **Dynamics**: involves the study of systems in motion while unbalanced due to unequal forces acting on the body.

Mechanics

- **Dynamics**: moving systems
  - **Kinetics**: Examines the forces acting on the body during movement and the motion with respect to time and forces
  - **Kinematics**: A branch of biomechanics that describes the motion of a body without regard to the forces that produce the motion
Mechanics

- Kinetics
  - Forces that cause, arrest, or modify motion in a system
    - Gravity
    - Muscles
    - Friction
    - External resistance

- Kinematics
  - Involves the time, space, and mass aspects of a moving system
    - The description of motion
      - Osteokinematics: the manner in which bones move
      - Arthrokinematics: movements occurring between joint surfaces

Kinematics - Types of Motion

- Translatory – Movement of a body in which all of its parts move in the same direction and distance and at the same speed
  - Rectilinear motion = straight-line motions (sliding surfaces)
  - Curvilinear motion = curved line of motion (the motion of a ball when tossed)

- Rotary
  - the arc of motion around a fixed axis of rotation or a "pivot point"
  - Joints have "pivot points" which are used as reference points from which to measure the range of motion (ROM) of that joint
Terminology

- Required to describe:
  - Movement
  - Position
  - Location of anatomic features

Anatomical Position

- Standing, Upright, Eyes forward, Feet parallel and close together, Arms at side, Palms facing forward
- Standard Reference Point
  - Axis of rotation
  - Planes of motion
  - Actions of muscles are referenced from anatomic position

Fundamental position

- Same as anatomical, except palms face side of body
Descriptive Terminology

- **Medial – Lateral**
  - Medial: Near to the median
  - Lateral: Away from the median
- **Anterior (Ventral) – Posterior (Dorsal)**
  - Anterior: In front of
  - Posterior: In the rear
- **Distal – Proximal**
  - Distal: Away from the trunk
  - Proximal: Towards the trunk
- **Superior – Inferior**
  - Superior: “above” in relation to another structure
  - Inferior: “below” another structure
- **Cranial/Cephalad – Caudal**
  - Cranial/Cephalad: closer to the head
  - Caudal: closer to the feet
- **Superficial – Deep**
  - Superficial: closer to the surface
  - Deep: below the surface
Terminology

- **Origin**: the proximal attachment of a muscle or ligament
- **Insertion**: the distal attachment of a muscle or ligament
- **Prone**: lying face down
- **Supine**: lying face up

Unilateral: Only one side
Bilateral: Refers to both sides

“Ipsilateral: Same side
Contralateral: Opposite side

Patient has decided to get a bilateral knee replacement
The left arm is ipsilateral to the left leg and contralateral to the right arm

Osteokinematics

- Motion of bones through a range of motion relative to the 3 cardinal planes of the body and around the axis in that joint
- **Planes**:
  - Frontal or Coronal
  - Sagittal or Median
  - Horizontal or Transverse
Frontal Plane
- Also referred to as the coronal plane
- Bisects the body from side to side and divides the body into equal front and back halves
  - Side to Side
  - Abduction and adduction are movements commonly performed in this plane.

Sagittal Plane
- Bisects the body from front to back, dividing it into right and left symmetrical halves
  - Front to Back
  - Movements which generally occur in this plane are flexion, extension, and hyperextension

Transverse Plane
- Also referred to as the horizontal plane
- Divides the body horizontally into superior (upper) and inferior (lower) halves
  - Parallel to the ground
  - Rotational movements such as spinal rotation and supination and pronation of the forearm occur in the transverse plane
Osteokinematics

- Axis of Rotation = "pivot point"
  - It's ALWAYS perpendicular to the plane of motion!
- Degrees of Freedom
  - The number of planes of motion allowed to a joint
    - The shoulder and hip have 3
    - The elbow and knee have just 1
    - The wrist has 2

Osteokinematics: Fundamental Motions

- Flexion and Extension:
  - Flexion = Bending; movement of one bone on another; Two segments approaching each other (usually anterior surfaces)
  - Extension = Straightening; movement of one bone away from another; Two segments moving away from each other

Osteokinematics: Fundamental Motions

- ABDuction & ADDuction
  - ABD = movement away from midline
  - ADD = movement toward midline
- Rotation
  - Internal Rotation = anterior surface moving toward midline (medial rotation)
  - External Rotation = anterior surface moving away from midline (lateral rotation)
Osteokinematics: Fundamental Motions

- **Circumduction**
  - Circular motion through 2 planes
  - If a joint can draw a circle in the air, it can circumduct

- **Protraction & Retraction**
  - **Protraction**
    - Translation of bone away from midline in a plane parallel to the ground
  - **Retraction**
    - Translation of bone toward midline in a plane parallel to the ground

- **Horizontal ABD & ADD**
  - Shoulder flexed or abducted to 90°
  - Horizontal ABD: movement away from midline
  - Horizontal ADD: movement towards midline

- **Pronation & Supination**
  - Takes place in the forearm with pronation turning the palm down and supination turning the palm up

- **Radial & Ulnar Deviation**
  - Takes place at the wrist with movement toward either the radius or ulna
Osteokinematics: Fundamental Motions

- **Dorsiflexion & Plantar Flexion**
  - Takes place at the ankle with dorsiflexion bringing the foot upward and plantar flexion pushing the foot down.

- **Inversion & Eversion**
  - The sole of the foot faces medially in inversion and laterally in eversion.

Kinematics of Motion

- **Movement of the body** = translation of the body’s center of mass
- **Center of Mass/Center of Gravity**

Mechanics

- **Arthrokinematics**
  - Manner in which adjoining joint surfaces move in relation to each other or how they fit together
  - helps to improve the movement of the joint
  - Parts may move in
    - the same direction
    - the opposite direction
Fundamental Movements: Joint Surfaces

- Roll
  - Multiple points maintain contact throughout the motion

- Slide
  - A single point on one surface contacts multiple points throughout the motion

- Spin
  - A single point on one surface rotates on a single point on the other surface

Roll & Slide Mechanics

- Convex on Concave
  - When a convex joint surface moves on a concave joint surface
    - The roll and slide occur in opposite directions

- Concave on Convex
  - When a concave joint surface moves about a stationary convex joint surface
    - The roll and slide occur in the same direction

Kinetics

- The effect of forces on the body
  - Force
    - Any action or influence that moves a body or influences the movement of a body
      - Forces that "control" movement of the body
        - Internal
          - Muscle contraction
          - Tension from ligaments
          - Muscle lengthening
        - External
          - Gravity
          - An external load
          - A therapist applying resistance or a free weight for resistance training
Kinetics

- Torque
  - The internal and external forces acting at a joint
  - The rotational equivalent of force
  - Torque = moment arm x force (resistance)

Mechanics

- Mass
  - Amount of matter that a body contains
- Inertia
  - Property of matter that causes it to resist any change of its motion in either speed or direction

Mechanics

- Mass is a measure of inertia
  - Resistance to a change in motion
Friction
- A force that is developed by two surfaces

Friction
- Tends to prevent motion of one surface across the other
- The coefficient of friction must be overcome for movement to occur

Friction
- It is easier to move across something once the coefficient of friction has been met.
The Human Body as a Machine

Levers
- **Lever**: a rigid bar that turns about an axis.
- **Force**
- **Axis**
- **Resistance**
- **The "Dog Principle"**
  - "A" in the middle
  - "R" in the middle
  - "F" in the middle

Levers

Biomechanical Levers
- Interaction of internal and external forces control movement and posture through a system of levers within the body.
- The body has Three Classes of Levers
  - **First Class**
    - Similar to a "see saw"
  - **Second Class**
    - The axis is located at one end to provide "good leverage"
  - **Third Class**
    - The axis is also at one end but gravity has more "leverage" than muscle meaning that more muscle force is needed to lift a small load
First Class Lever
- Force-Axis-Resistance
- Axis is in the middle

Biomechanical First Class Lever
- Axis always is in the middle
- Designed for balance
- Distance between axis and resistance (load) will dictate how easy it is to move it

First Class Lever
- FA shorter than RA
- FA longer than RA
Second Class Lever

- Axis - Resistance - Force
- Resistance is in the middle
- Always increases the effort force

Biomechanical Second Class Lever

- Resistance is in the middle
- Designed for good leverage
  - Small force can lift large load
- Very few examples of 2nd class levers in body

Third Class Lever

- Axis - Force - Resistance
- Force applied in the middle
- Always increases the effort force
Biomechanical Third Class Lever

- Force is in the middle
- Designed for motion
  - The most common lever in the body because they favor large ranges of motion
  - Favor speed and distance

Factors In Use of Anatomical Levers

- Force Arm: the distance between the axis and the point of force.
- Resistance Arm: The distance between the axis and the point of resistance.

Mechanical Advantage

- Ratio between the force arm and the resistance arm
  \[ \text{Force Arm} = \text{Resistance Arm} = \text{Mechanical Advantage} \]

- If quotient >1:
  - \( FA > RA \): mechanical advantage in force
    - 1st and 2nd Class

- If quotient <1:
  - \( FA < RA \): mechanical advantage in speed and range of motion
    - 1st and 3rd Class: This lever can not give any mechanical advantage. Regardless of where you apply the force, the force you apply must always be greater than the force of a load.
Mechanical Advantage

- It takes less force on your part if you apply resistance distally rather than proximally.
- Mechanical Advantage decreases the more distal you go.

(Bio) Mechanical Advantage

- Levers:
  - Origin and insertion of a muscle dictate mechanical advantage.
    - If the insertion point of muscle is further away from the **axis (joint)**, this requires a less powerful movement.
    - But moves it a smaller distance.

Pulleys

- A Pulley
  - A grooved wheel that turns on an axel with a rope or cable riding in the groove.

- Function
  - To change the direction of a force (fixed).
  - Majority of pulleys found in the body.
  - To increase or decrease the magnitude of a force (moving).
Biomechanical Pulleys

- In the human body, in most cases the pulley is replaced by a bone, cartilage or ligament and the cord is replaced by a muscle tendon.
  - Pulley-like

- The tendon is lubricated in a manner so that it may easily slide over the pulley.

Line of Pull

- A muscle’s line of pull describes the direction of muscular force which can be represented in a vector. (the motions that are possible)

- A muscle’s line of pull and the joint’s axis of rotation determines what action/motions a muscle can produce

- If a muscle crosses a joint, it acts on that joint.

A Kinesiological Analysis is a Summary of all Components of A Movement

- Anatomy used for the activity
- Directional terminology
- Planes of motion
- Types of bones and joints
  - Types of levers
  - Mechanical advantages
- Types of muscle contractions
- Laws of motion
- Balance, Equilibrium, and Stability