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: 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
Mechanics

- 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: Nearer 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
**Terminology**

- Unilateral: Only one side
- Bilateral: Refers to both sides

“Patient has decided to get a bilateral knee replacement”

- Ipsilateral: Same side
- Contralateral: Opposite side

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

http://www.youtube.com/watch?v=rRIz6oOA0Vs&feature=related
Osteokinematics: Fundamental Motions

- **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
Osteokinematics: Fundamental Motions

- **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 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 “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
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 2\textsuperscript{nd} 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
  
  Force Arm $\div$ Resistance Arm = 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 dictates 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
Kinesiology: Form & Function