Canvas

- Assignments: drop box for posting your answers in a single Word/PDF file
- Files
  - Syllabus: syllabus, schedule changes if any (Syllabus posted)
  - Homework: homework assignments (HW1 posted, due 23:59, 17/09, next Fridayday) and solutions
  - Lecture Notes: preview and final versions (Lect 1 both versions posted, Lect 2 preview version posted)
- Panopto Recordings: Videos of lectures (Lect 1 posted)
- Zoom: Links to lectures and office hours

Review

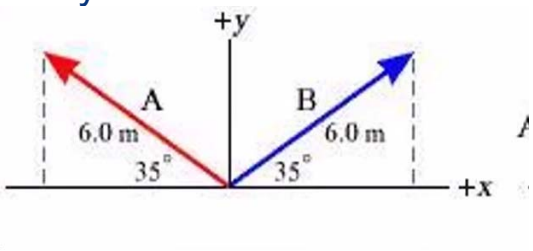
- **Biomechanics** is the study of forces acting on body and body segments; and the consequences of those forces
- Two Main Areas of Biomechanics
  - Improvement Performance
  - Prevent Injury
- More general goals
  - Theory and techniques needed for the development of various biomedical devices.
- In Biomechanics we use SI units
- **Fundamental Units**
  - Time (s)
  - Length (m)
  - Mass (kg)
  - Force (N) N = kg x 9.81

Review

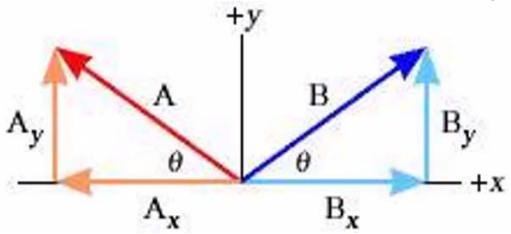
- **CoG** and **CoM** are inter-changeable (on earth)
- The Force of Gravity acts through the CoG
- CoG can move within the object if mass distribution changes
- A projectile's Axis of Rotation is its CoG
- Rigid Body Mechanics examines Static and Dynamic movements
- Dynamics breaks down into Kinematics and Kinetics
- Kinematics is not concerned with forces; Kinetics is
- Vectors have Direction and Magnitude; Scalar just has magnitude
- Positive and Negative denotes direction

Vector Resolution & Addition

- We break vectors down to horizontal and vertical components to analyze

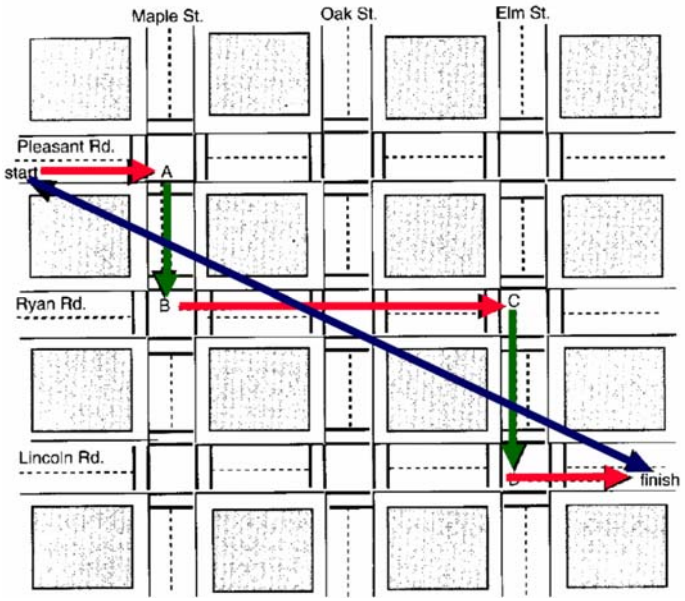


- Resultant—The resultant Vector is the combination of the horizontal vector and the vertical vector
  - A is the Resultant of A_x and A_y



Distance & Displacement

- Describing change in linear or angular position
- Distance (scalar): length of path
- Displacement (vector): difference between starting and finishing positions; independent of path
- Symbols
  - linear - *d* (m, cm, km)
  - angular – *θ* (degrees, radians, revolutions)



1 rev = 2π rad (6.28 rad) = 360°

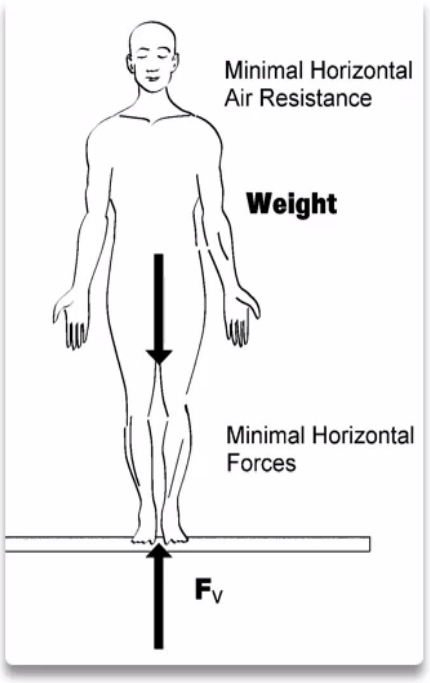
1 rad = 57.3°

Speed & Velocity

- Describing the rate of change of linear or angular position with respect to time
- Speed or velocity: Rate at which a body moves from one position to another
  - Speed (scalar)
  - Velocity (vector)
- Linear (m/s, km/hr, ft/s, mph)
  - Average $\bar{v} = \frac{\Delta d}{\Delta t}$ Instant $v = \frac{dd}{dt}$
- Angular (deg/s, rad/s, rpm)
  - Average $\bar{\omega} = \frac{\Delta \theta}{\Delta t}$ Instant $\omega = \frac{d\theta}{dt}$

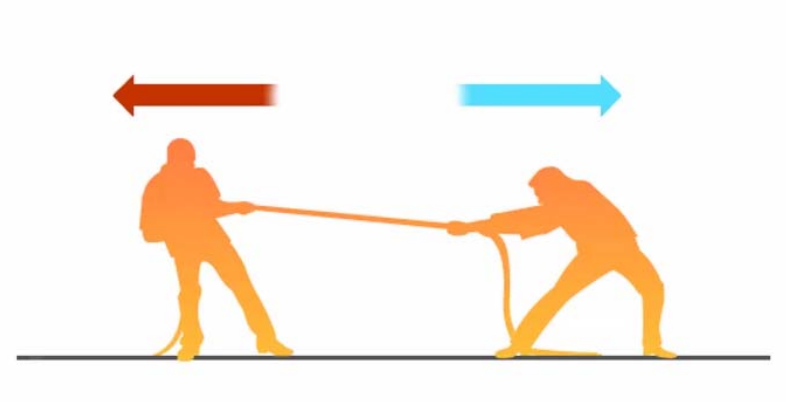
Free Body Diagrams

- Simplified representations of an object or system with forces acting on the object drawn on



What is a force?

- Simply: A Push or a Pull
- A bit more specific: An interactional push or pull effect between two bodies
- Key Points
  - Vector
  - Units: Newtons (N)
  - 1kg x 9.81m/s^2 = N



Internal vs External Forces

- Internal Forces
  - Forces that acting within the object or system whose motion is being investigated.
- External Forces
  - Forces that act on an object as a result of its interaction with the environment surrounding it.

Internal Forces

- Action / Reaction forces act on different parts of the system (body)
- Act in Opposition
  - Does not affect the motion of the whole body
- Tension
  - Tensile/Pulling Forces
  - Muscle-Tendon-Bone
- Compression
  - Compressive/Pushing Forces
  - Bone - Cartilage

External Forces

- Contact Forces
  - Occurs when objects are in contact with each other
  - Ex: Friction
- Non-Contact Forces
  - Occurs even if objects are not in contact with each other
  - Ex: Gravity

Figure 1.1 The forces acting on a shot-putter and a shot at the instant before release.

Net Force

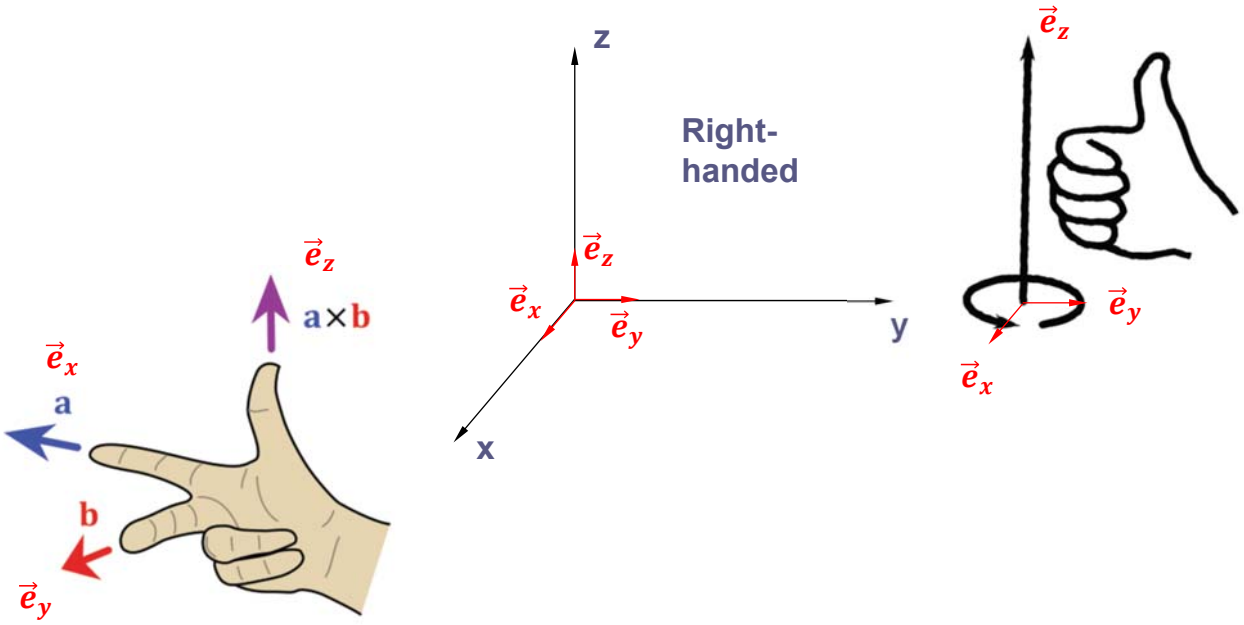
- Net
  - Defined as the sum or total
- Net Force
  - Is the total sum of all forces acting on an object
  - ΣF
- Used to help determine and describe cause of motion

Inertia, Mass, and Weight

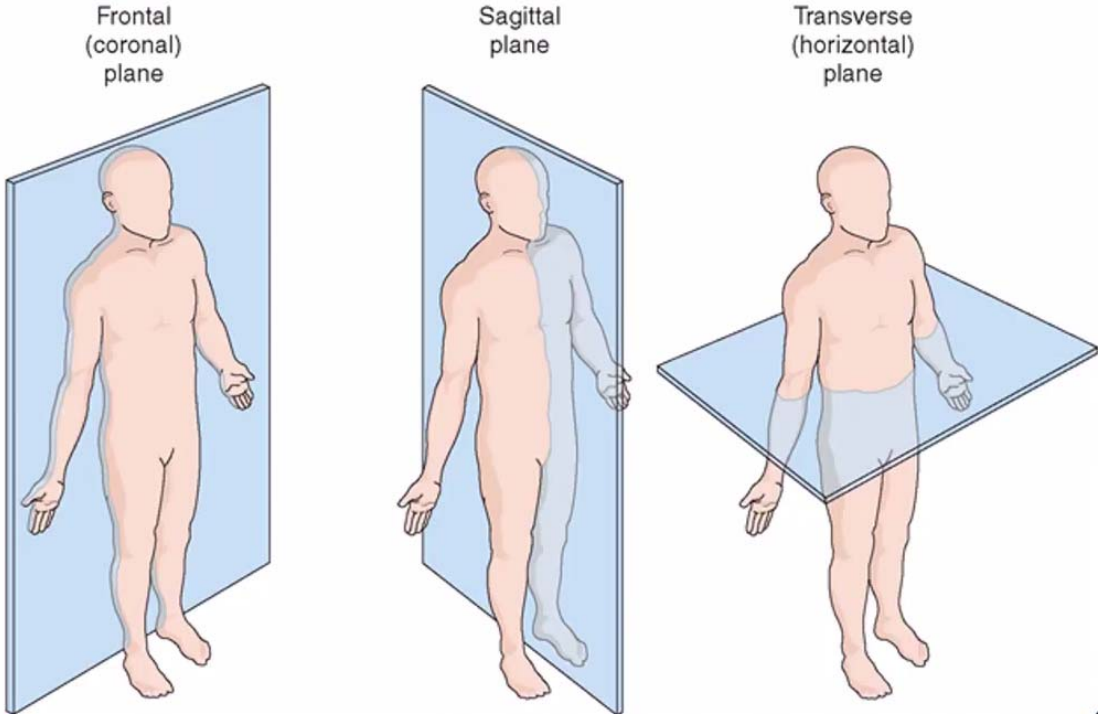
Inertia:	Mass:	Weight:
• An object's resistance to change in motion • Measured by Mass	• Is the measure of Inertia • Quantify of matter • Measured in Kg • Large or Small?	• Weight is the measure of the force of gravity acting on an object • Measured in Newtons • W = mg • N = kg (9.81m/s^2)

Coordinate Systems

- Cartesian system (right-handed)



The Anatomical Planes



Anatomical Planes & Axis of Rotation

- Anatomical Planes
  - Transverse Plane
  - Frontal Plane
  - Sagittal Plane
- Axis of Rotation
  - Anteroposterior (AP) Axis
    - Transverse Plane
    - Sagittal Plane
  - Mediolateral/Traverse Axis
    - Transverse Plane
    - Frontal Plane
  - Longitudinal Axis
    - Frontal Plane
    - Sagittal Plane

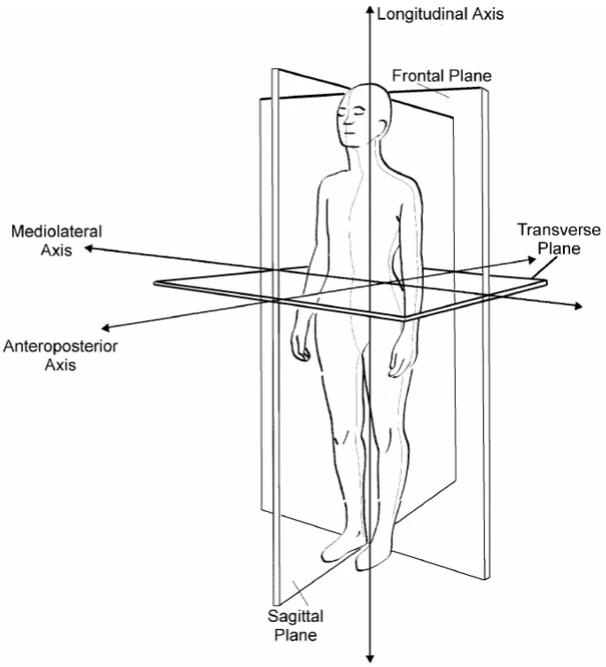


Figure 3.1. The major anatomical planes of motion, and axes of rotation.

The Axis of Rotation

Table 6.1 Anatomical Planes of Motion and Their Corresponding Axes of Motion

Plane	Axis
Sagittal	Transverse
Frontal	Anteroposterior (AP)
Transverse	Longitudinal

If you can identify either the plane or the axis of motion, the other is easily identified.

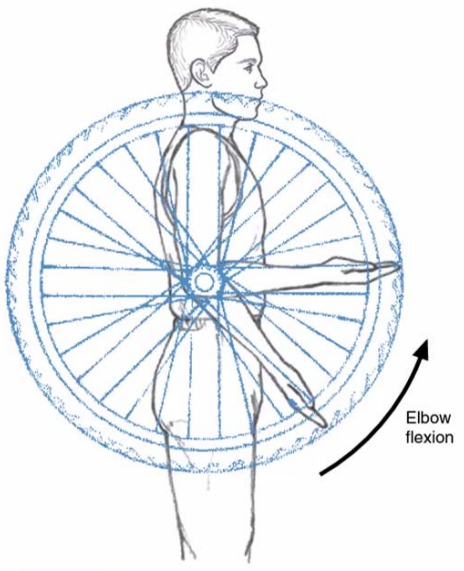


Figure 6.15 Imagining a bicycle wheel can help you identify the plane and axis of motion.

Sagittal Plane Joint Actions

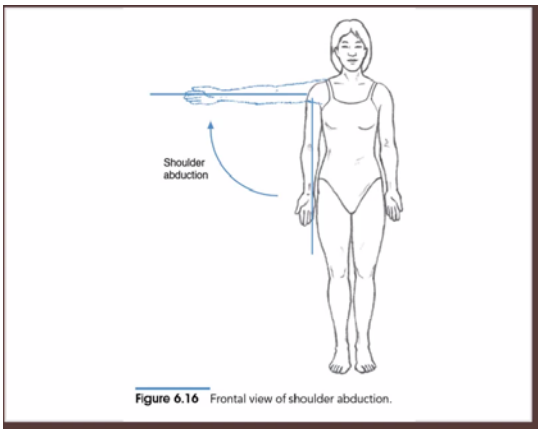


Figure 6.16 Frontal view of shoulder abduction.

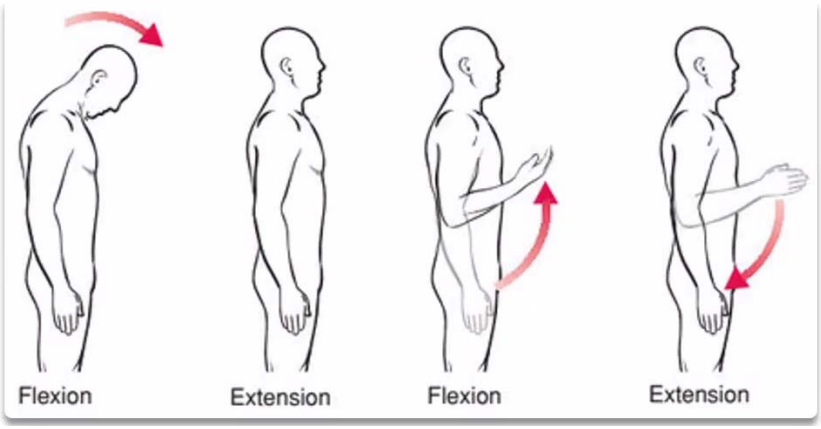
To the LEFT you can see the Abduction in the frontal plane. BELOW you cant see much of the movement in the sagittal or transverse planes

Tip: Look for which plane can you see the movement happing in

Figure 6.17 Sagittal *(a)* and transverse *(b)* views of shoulder abduction.

Sagittal Plane Joint Actions

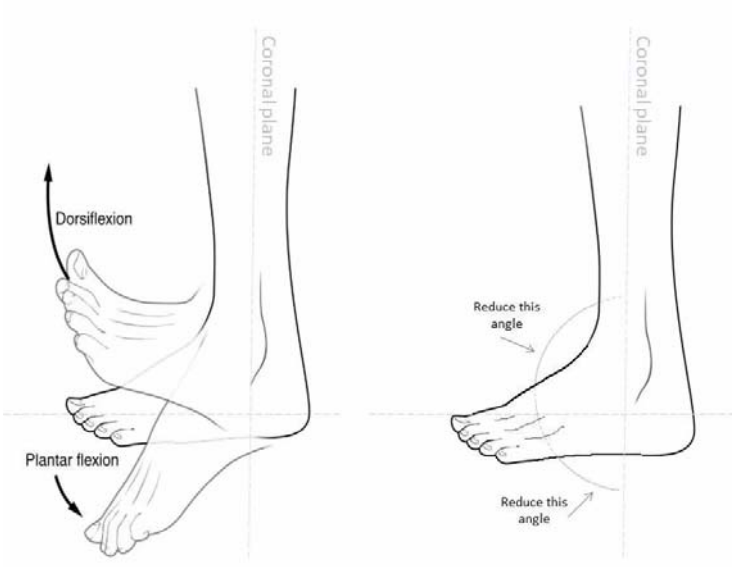
- Medical-Lateral Axis of Rotation
  - Flexion—Decreasing of joint angle
  - Extension—Increasing of the joint angle
- DorsiFlexion & Plantar Flexion
- Hyper Extension



DorsiFlexion & Plantar Flexion

- Ankle Specific

- Dorsiflexion brings the toes up
- Plantar flexion points them down



Sagittal Plane Joint Actions

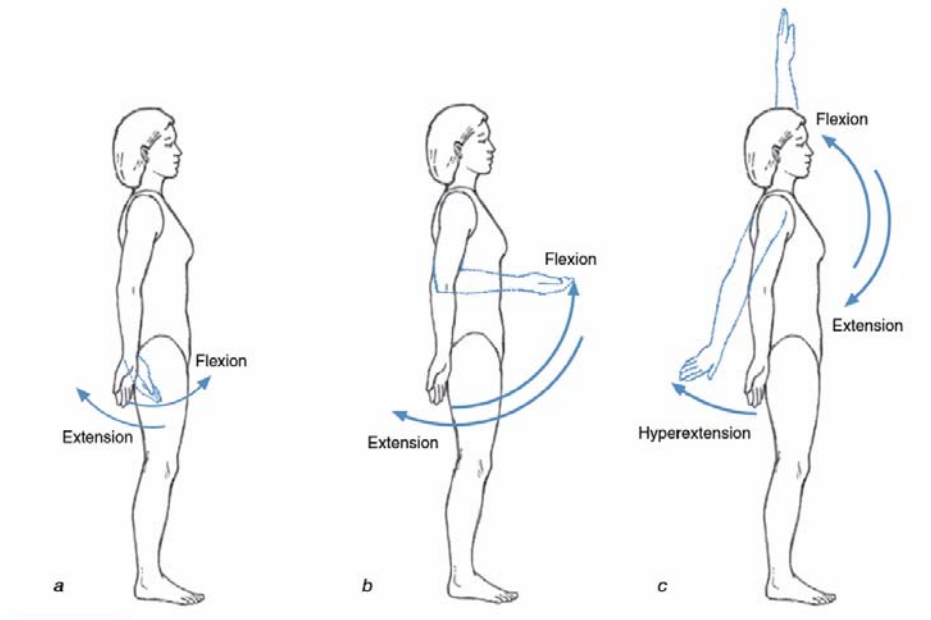
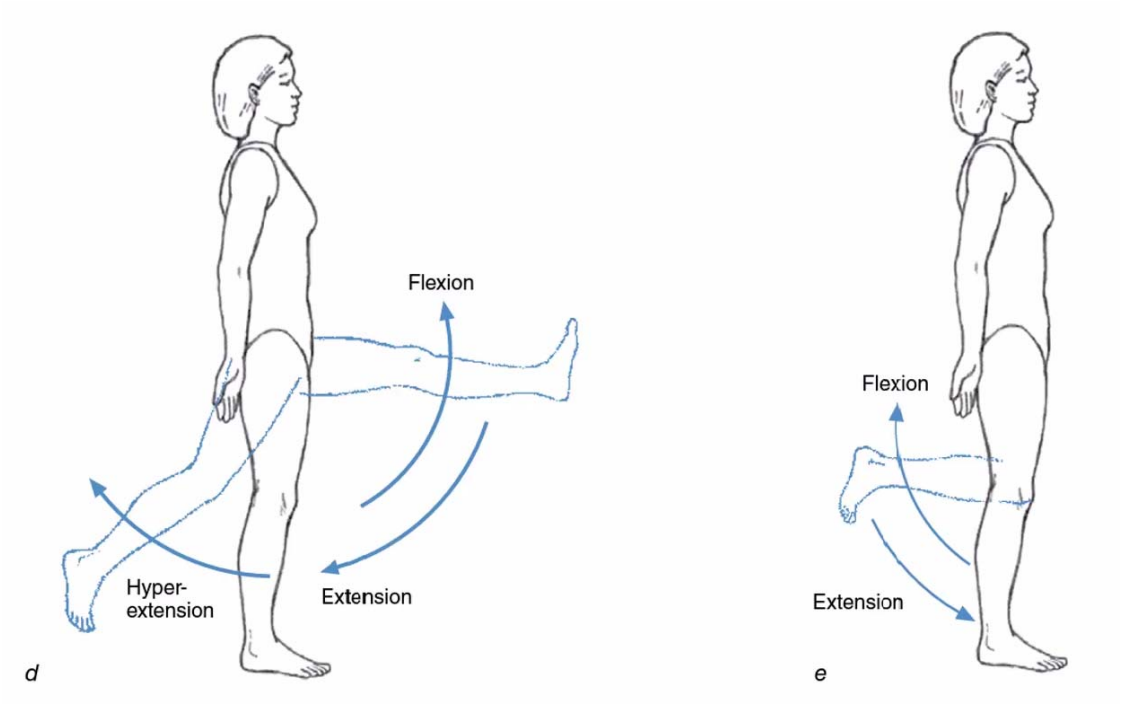


Figure 6.20 Sagittal plane joint actions at the wrist, elbow, shoulder, hip, knee, trunk, and neck and ankle.

Sagittal Plane Joint Actions



Sagittal Plane Joint Actions

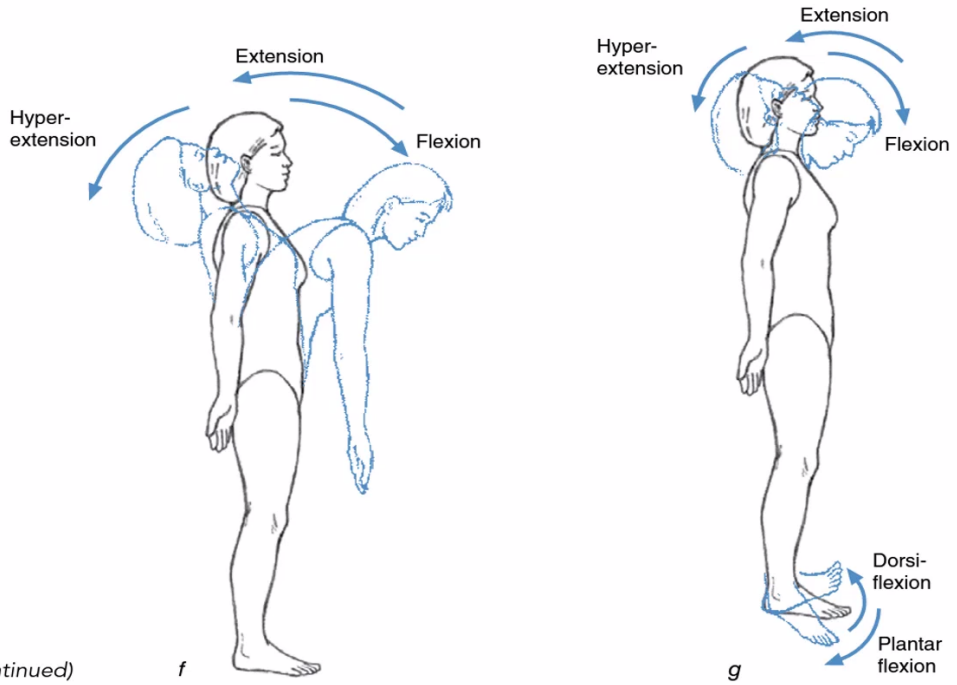
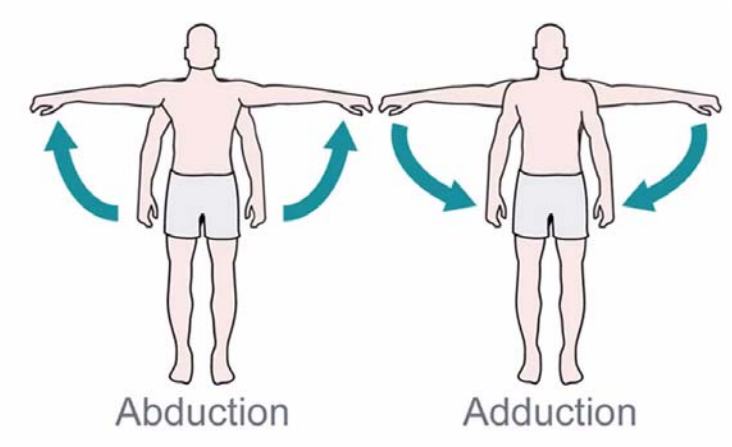


Figure 6.20 *(continued)*

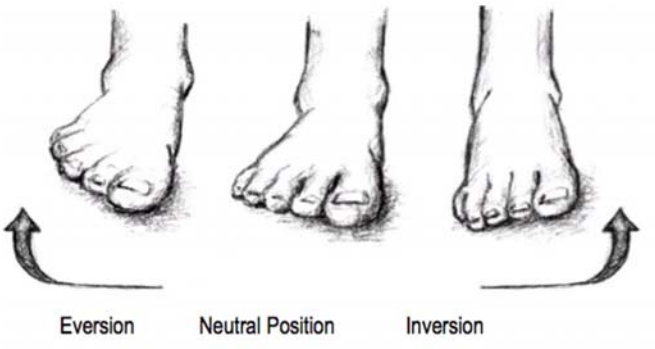
Frontal Plane Joint Actions

- Anterior-Posterior axis of rotation
  - Abduction & Adduction
    - Abduction is moving AWAY from the body
    - Adduction is moving TOWARDS the body
  - Inversion & Eversion
  - Ulnar & Radial Deviation



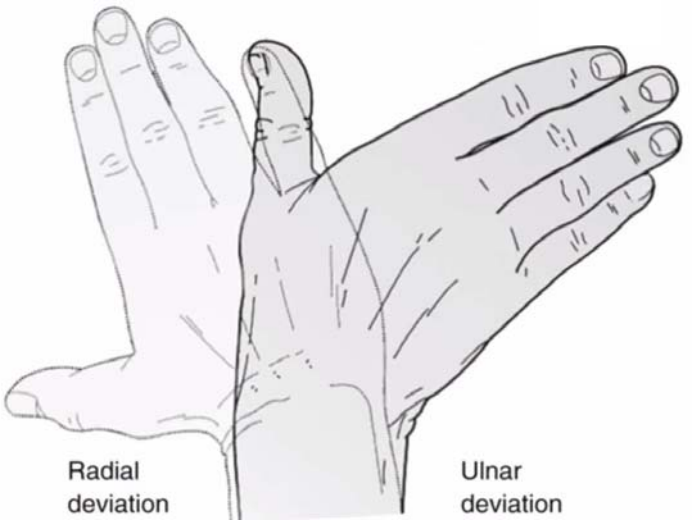
Frontal Plane Joint Actions

- Anterior-Posterior axis of rotation
  - Abduction & Adduction
  - Inversion & Eversion
    - Inversion the sole of the foot rotates in
    - Eversion the sole of the foot rotates out
  - Ulnar & Radial Deviation

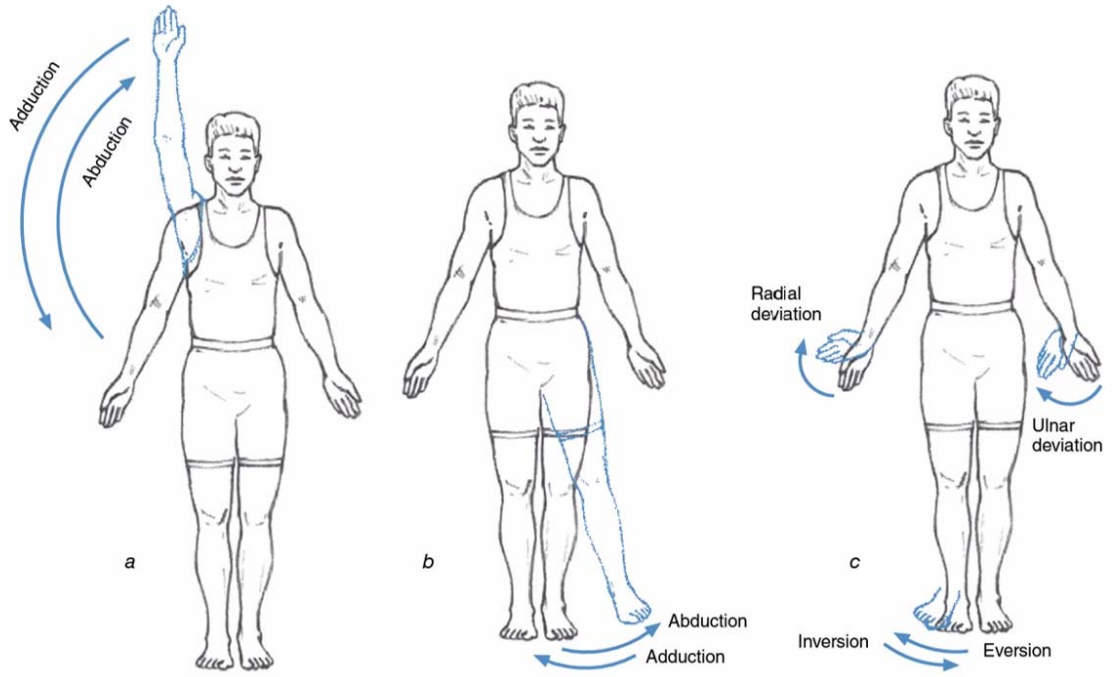


Frontal Plane Joint Actions

- Anterior-Posterior axis of rotation
  - Abduction & Adduction
  - Inversion & Eversion
  - Ulnar & Radial Deviation
    - Radial moves thumb towards wrist
    - Ulnar moves thumb from wrist



Frontal Plane Joint Actions



Frontal Plane Joint Actions

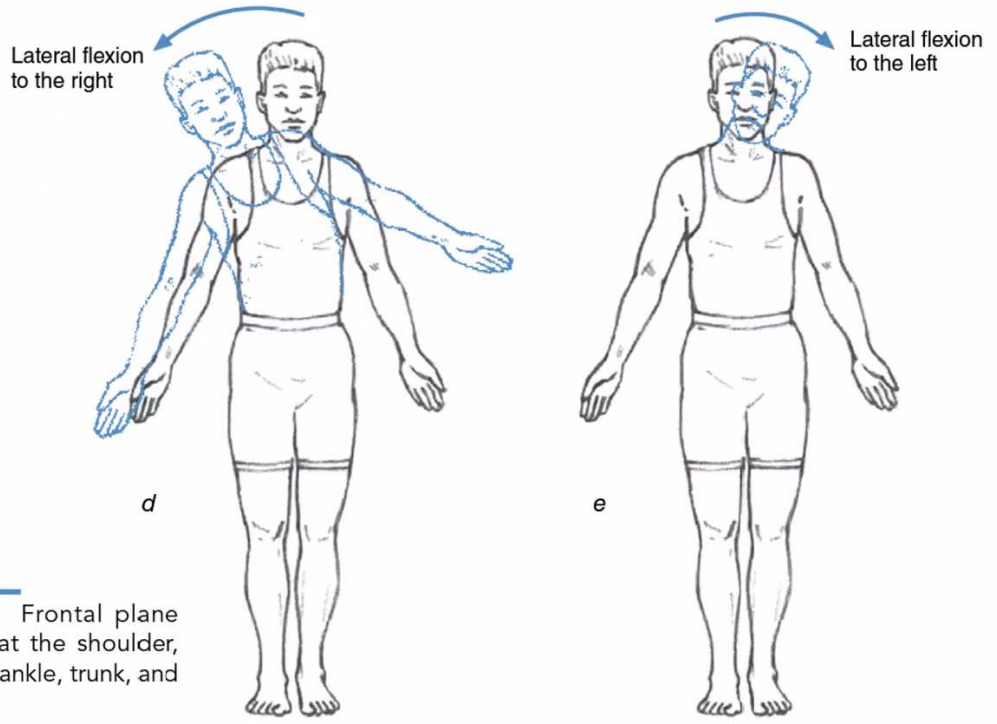
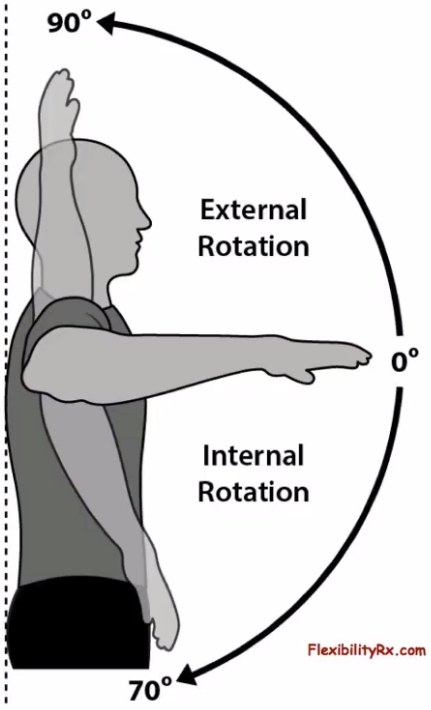


Figure 6.21 Frontal plane joint actions at the shoulder, hip, wrist and ankle, trunk, and neck.

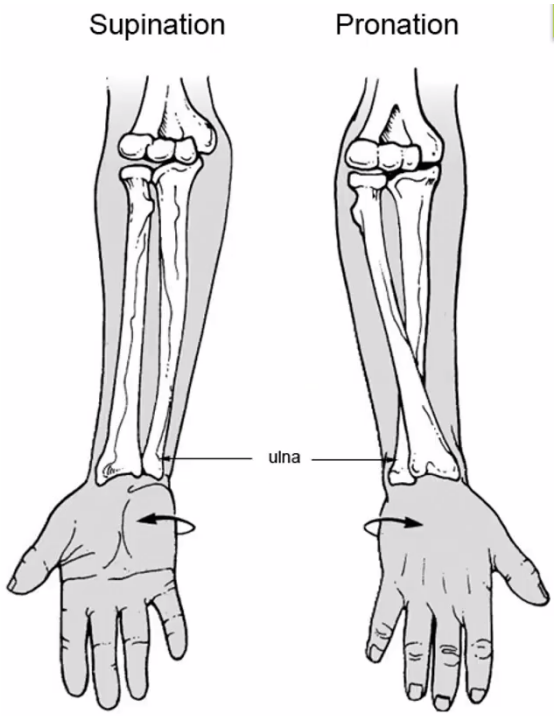
Horizontal/Transverse Plane Joint Actions

- Longitudinal axis of rotation
  - Internal & External Rotation
    - Internal Rotation rotates towards body
    - External Rotation rotates away from body
  - Pronation & Supination
  - Horizontal Abduction & Adduction



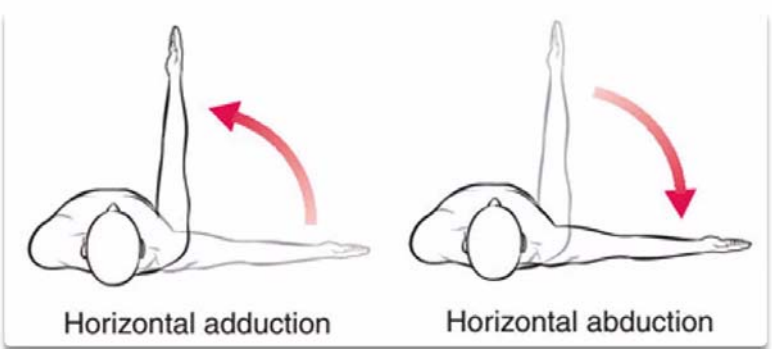
Horizontal/Transverse Plane Joint Actions

- Longitudinal axis of rotation
  - Internal & External Rotation
  - Pronation & Supination
    - Supination—Palms up
    - Pronation—Palms down
  - Horizontal Abduction & Adduction

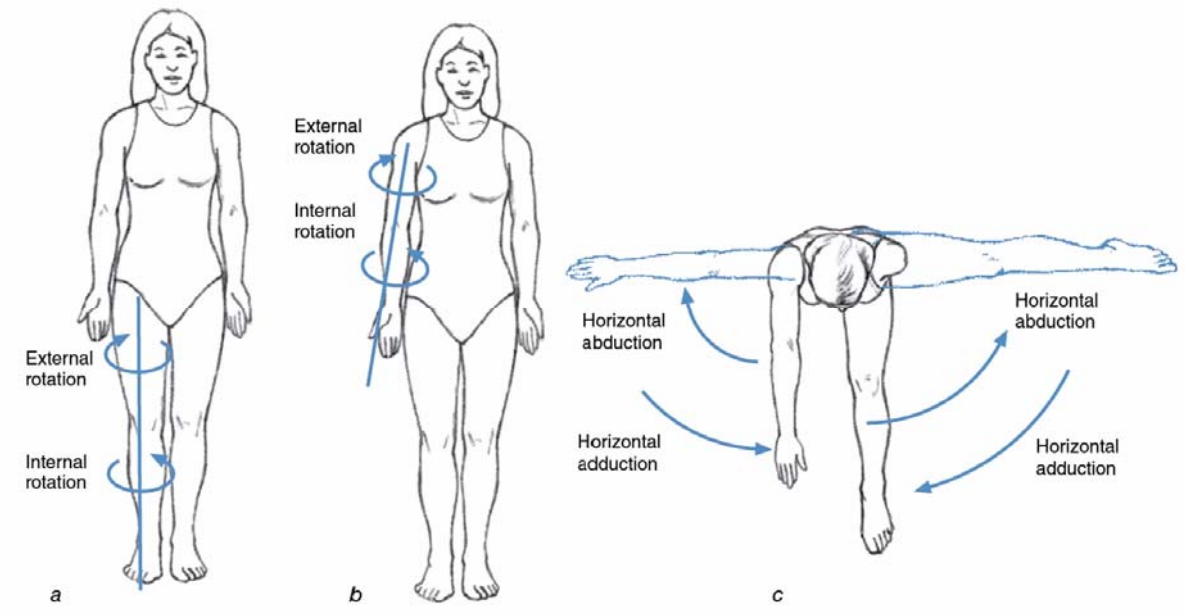


Horizontal/Transverse Plane Joint Actions

- Longitudinal axis of rotation
  - Internal & External Rotation
  - Pronation & Supination
  - Horizontal Abduction & Adduction
    - Abduction is away from the body
    - Adduction is towards the body



Horizontal/Transverse Plane Joint Actions



Horizontal/Transverse Plane Joint Actions

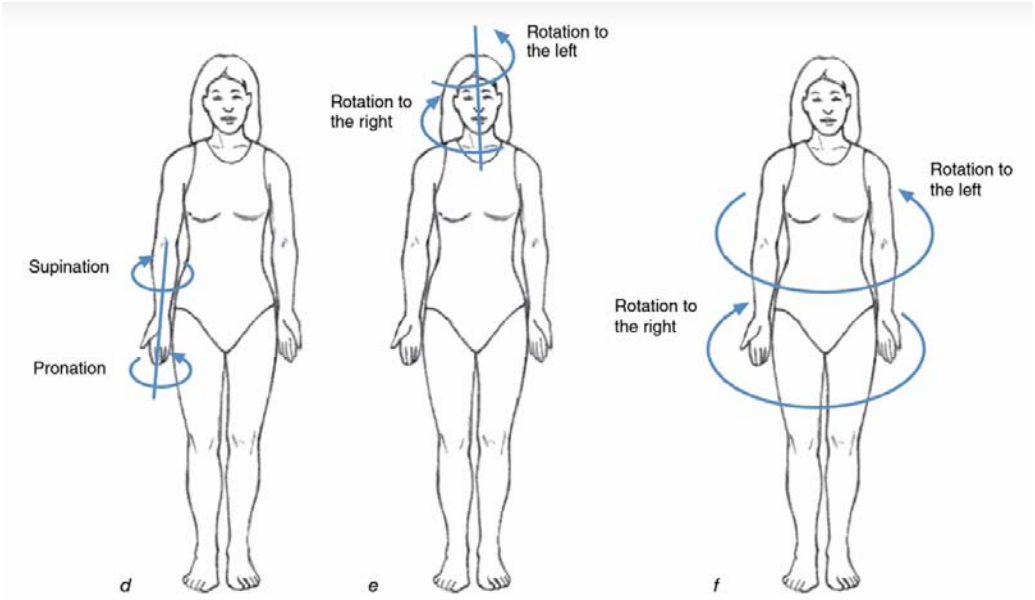


Figure 6.22 Transverse plane joint actions at the hip, shoulder, shoulder and hip, radioulnar joint, neck, and trunk.

Range of Motion (RoM)

- The overall motion used in a movement
  - Can be in angular terms (ex. Knee angle) or linear terms (ex. CoM Height)
  - The RoM is dictated by the goal/purpose of a moment.

Range of Motion (RoM)

- If
  - Low effort is needed (Low Force and/or Low Speed)
  - High Amounts of Accuracy are Needed
- Small Range of Motion will be used.

Range of Motion (RoM)

- If
  - High Effort is Needed (High Force and/or High Speed)
  - Low Amounts of Accuracy are Needed
- Large Range of Motion will be used.

Principle of Balance

- Balance is a person's ability to control their body position relative to some base of support.

Stability & Mobility

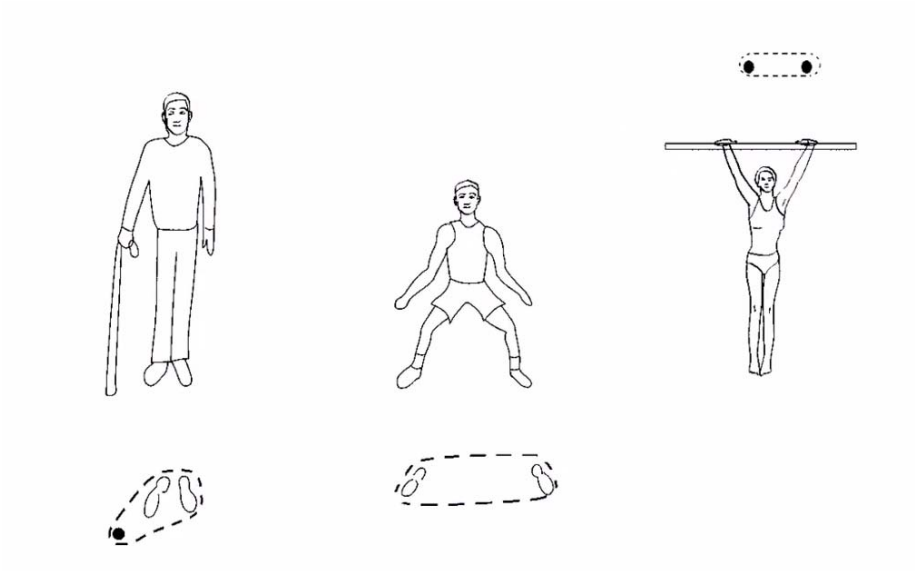
- Balance is the tradeoff between Stability & Mobility
- Stability—a body position that resists changes to body position
- Mobility—a body position that facilitates changes to body position
- Inversely Related:
  - A highly stable position is not very mobile
  - A highly mobile position is not very stable
- Optimal postures require the right mix of both!

Modifying Stability & Mobility

- Two biomechanical factors contribute to Stability & Mobility
  - The Base of Support
  - The position of the CoM relative to the base of support

Base of Support

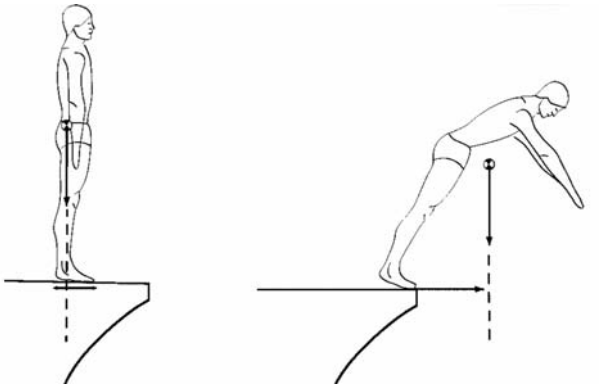
- Area formed by support segments or areas of the body
  - Key point: Larger = More Stable



CoM & Base of Support

- The closer the CoG is relative to the base of support, the more stable
  - Mobile Position

  - Stable Position

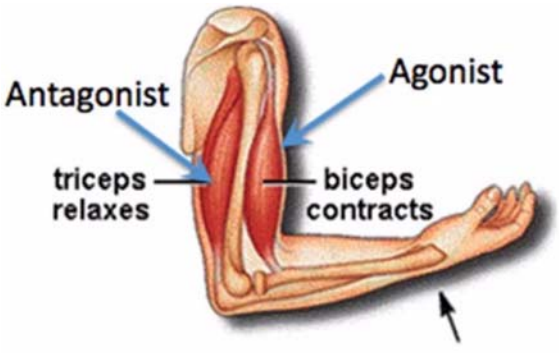


Muscle Actions

- Terms to be familiar with
  - Active vs passive
  - Agonist vs Antagonist
  - Isometric vs Eccentric vs Concentric
- Active Muscle
  - Active muscles are activated while changing length
  - Either facilitating shortening or resisting lengthening
- Passive Muscle
  - Passive muscles are not activated while changing length
  - Either being stretched by another force or shortened due to 'elastic' tension

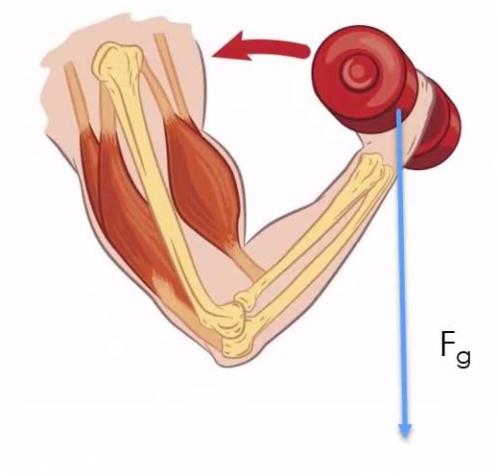
Agonist vs Antagonist Muscles

- Agonist Muscle
  - The primary muscle (or muscle group) responsible for the movement
  - Synergist: A smaller muscle that aids the agonist but isn't the primary mover
  - Active during movement
- Antagonist Muscle
  - The muscle (or muscle group) opposite or opposing the agonist muscles
  - Typically passive during movement



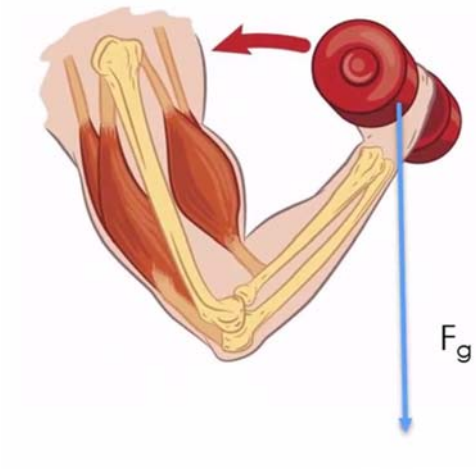
Concentric Muscle Action

- Active shortening of a muscle
- When the muscle is active and its attachments draw close together
- During the phase of movement that is moving AGAINST the line of force
- Example
  - Bicep (Agonist) is concentric on upward phase of a bicep curl
  - Line of force (gravity is down)
  - Tricep (Antagonist) is passive



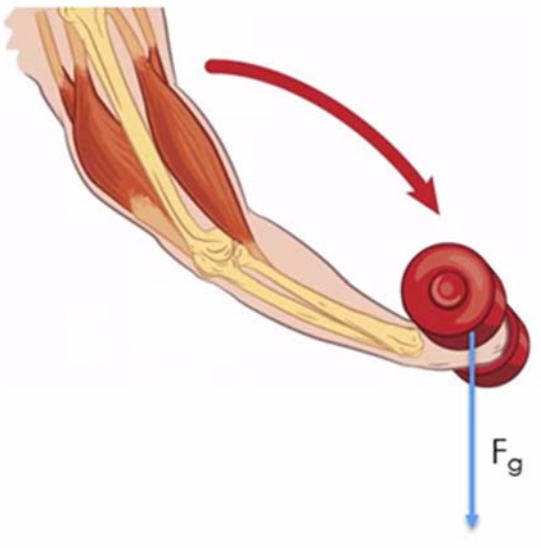
Concentric Action Occurs…

- When the …
  - Flexors activate and flexion happens
  - Extensors activate and extension happens
  - Abductors activate and abduction happens



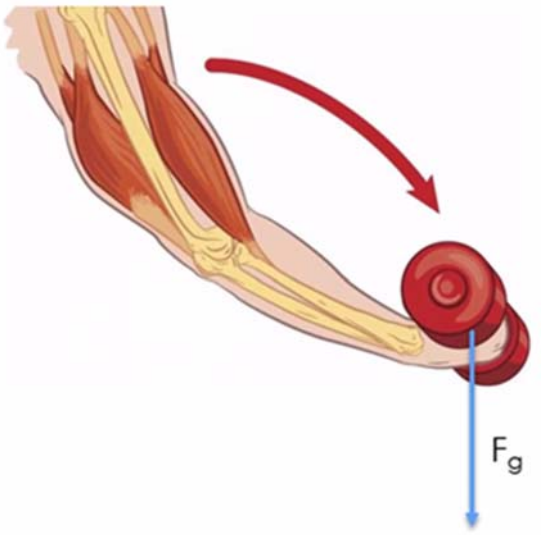
Eccentric Muscle Action

- Active lengthening of a muscle
- When the muscle is active and its attachments draw further together
- During the phase of movement that is moving WITH the line of force
- This muscle is RESISTING the lengthening of the muscle
- Example
  - Bicep (agonist) is eccentric on downward phase of a bicep curl
  - Line of force (gravity is down)
  - Tricep (Antagonist) is passive



Eccentric Action Occurs…

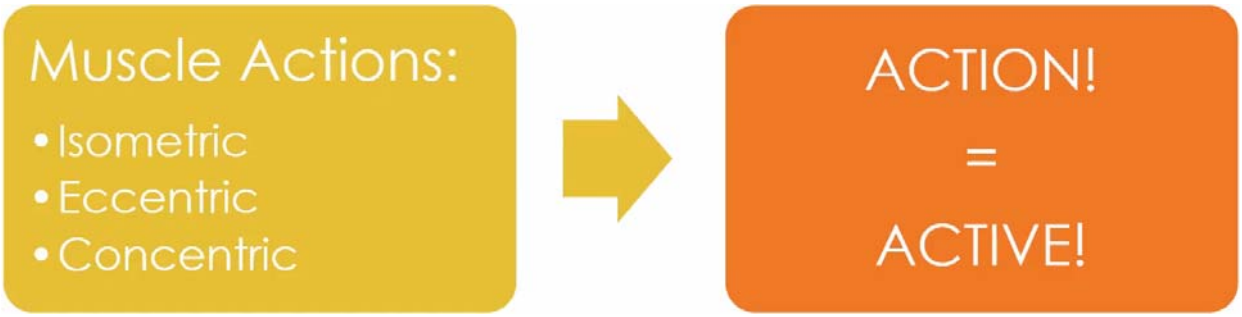
- When the …
  - Flexors activate and extension happens
  - Extensors activate and flexion happens
  - Abductors activate and adduction happens



Isometric Muscle Action

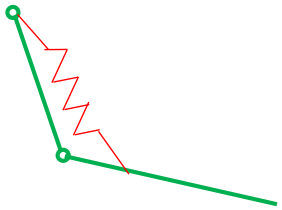
- Muscles are activated but do not change length
- Exerting force, but not moving

Key Point



Summary

- Agonist Muscles are your active muscles / Antagonist muscles are their counterparts
- Your Agonist will be Active throughout a movement / Your antagonist will be passive
- Concentric Muscle action is an active shortening of the muscle, moving against the line of the force
- Eccentric Muscle action is an active lengthening of the muscle, moving with the line of the force
- Isometric Muscle action is muscle activation with no change in muscle length



Tutorial 1

- 1. A new trail leads a hiker down a path which winds 5 km due east, 7 km north, 3 km east, and 4 km south. What was the total distance traveled? What was total displacement? Relative to the start of the trail, what was the direction of the total displacement vector?

Tutorial 1

- 2. If the hiker in the previous problem completed the entire trail in 7 hours, what was the average speed of the hiker? What was the magnitude of the average velocity?

Tutorial 1

- 3. A cyclist travels 40 miles in one hour. Use Figure 1 below to answer the following questions.
  - a. What was the average speed during the first 20 minutes of the ride in mph?
  - b. What was the average speed during the last 40 minutes of the ride in mph?
  - c. What was the average speed during the entire ride in mph?

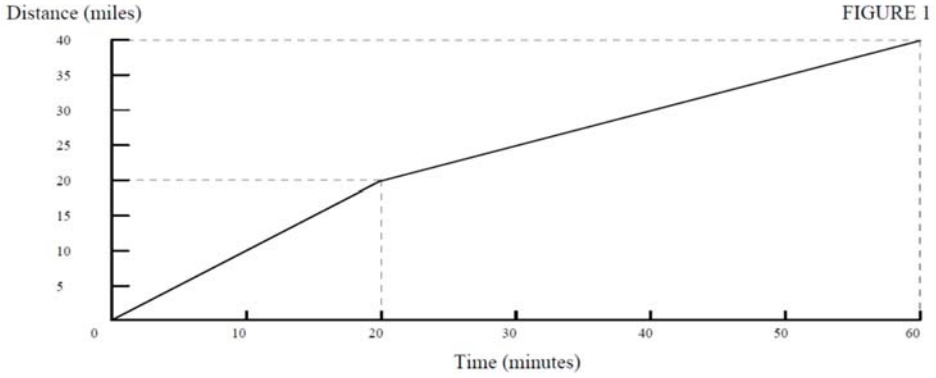


FIGURE 1

Tutorial 1

- 4. At the instant of take-off, a long jumper has a forward velocity of 32 ft/sec and a vertical velocity of 12 ft/sec. Find the angle of take-off (relative to the horizontal), and the magnitude of the resultant velocity vector.

Tutorial 1

- 5. A figure skater completes a double axle (2 complete rotations) in 0.5 seconds. Calculate the skater's average angular velocity in a) deg/sec, and b) rad/sec.

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- 6. If the skater in the previous problem manages to stop spinning in a time of 1.5 seconds, what was the average angular acceleration during this period (in deg/s)?

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- 7. What is the net force acting on the gymnast if she maintains this static position? Draw and label each of the forces acting on the gymnast in this situation. Identify each of the reaction forces.

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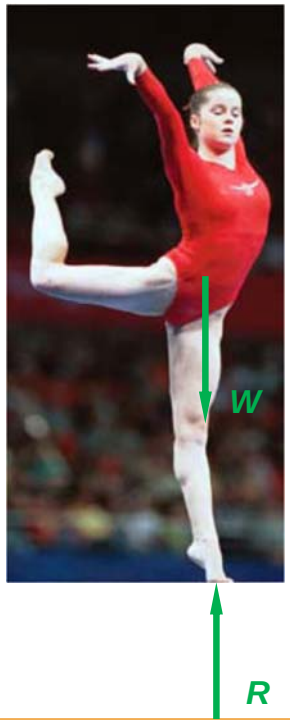

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- 8. The basis $\{\vec{e}_x, \vec{e}_y, \vec{e}_z\}$ has a right-handed orientation and is orthonormal.
  - (a) Determine $|\vec{e}_i|$ for $i = x, y, z$.
  - (b) Determine $\vec{e}_i \cdot \vec{e}_j$ for $i, j = x, y, z$.
  - (c) Determine $\vec{e}_x \cdot \vec{e}_y \times \vec{e}_z$.
  - (d) Why is: $\vec{e}_x \times \vec{e}_y = \vec{e}_z$?

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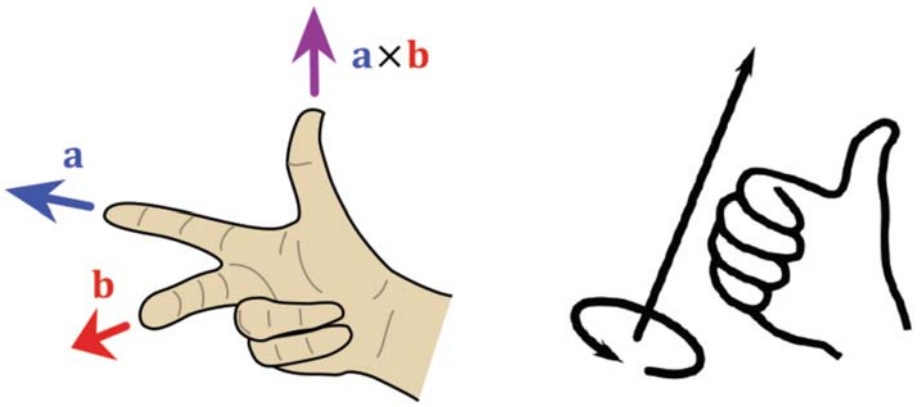

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- 9. Let $\{\vec{e}_x, \vec{e}_y, \vec{e}_z\}$ be an orthonormal vector basis. The force vectors $\vec{F}_x = 3\vec{e}_x + 2\vec{e}_y + \vec{e}_z$ and $\vec{F}_y = -4\vec{e}_x + \vec{e}_y + 4\vec{e}_z$ act on point P. Calculate a vector $\vec{F}_z$ acting on P in such a way that the sum of all force vectors is the zero vector.