ECE 370
Introduction to Biomedical Engineering

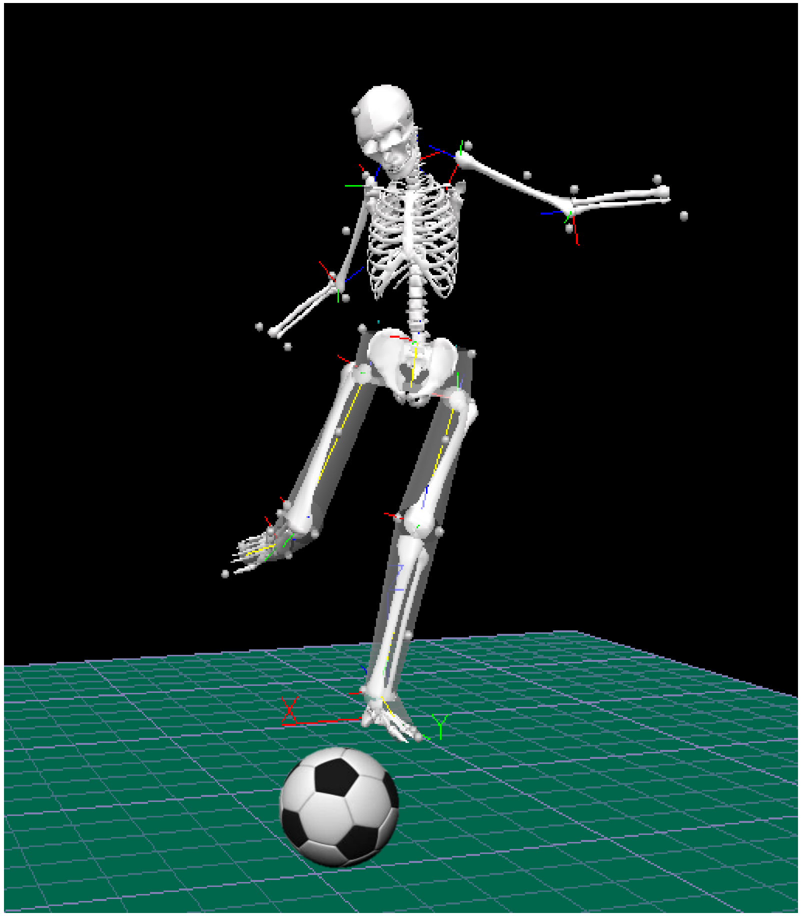
Principles of Biomechanics

Introduction

- **What is Biomechanics?**
  - The study of internal and external forces acting on the body segments, and the effects produced by these forces.
  - The principles of engineering, specifically mechanics, applied to human movement.
  - Kinesiology
    - Study of movement
    - Tends to focus on neuro musculoskeletal systems
- **Problems studied by biomechanists**
  1. How can human performance be enhanced?
  2. How can injuries be prevented?
  3. How can rehabilitation from injury be expedited?
- **Areas of Biomechanics**
  - Sports Biomechanics
  - Occupational Biomechanics
  - Clinical Biomechanics

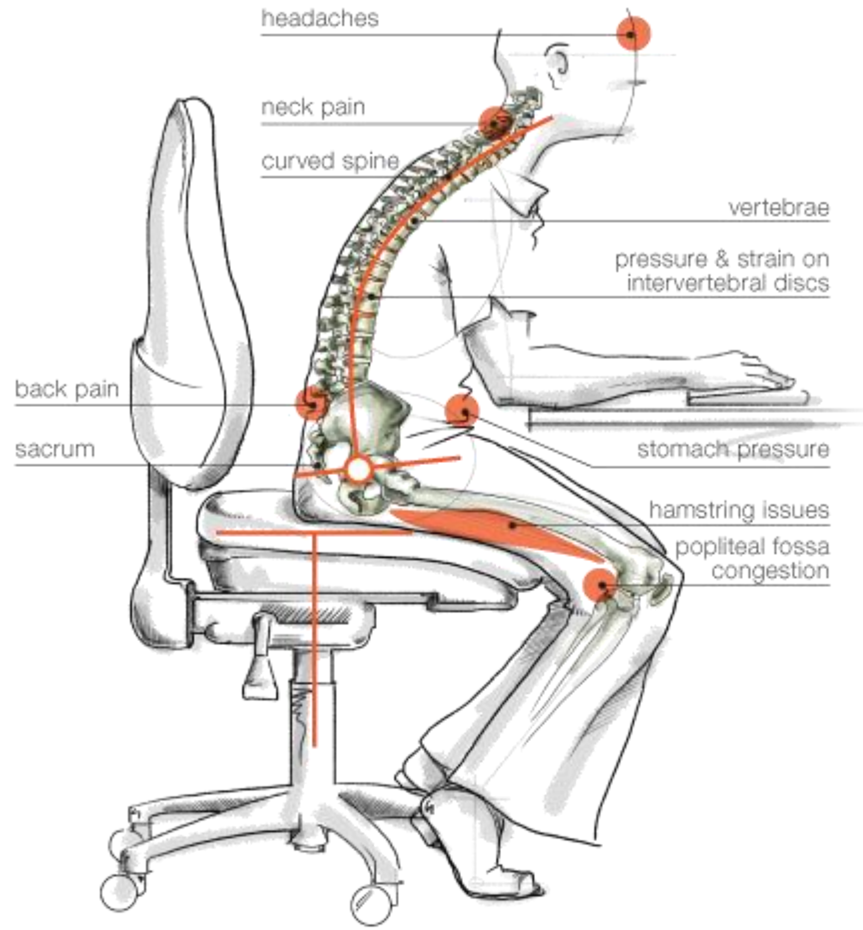
Sports Biomechanics

- **Understanding and applying mechanical concepts to**
  - Assess the most optimal way to move the body
  - Achieve maximal performance
  - Minimize risk of injury



Occupational Biomechanics

- **Design machines and the workplace to**
  - Reduce repetitive stress on workers' joints
  - Minimize injuries and long term problems



Clinical Biomechanics

- **Analyze the mechanics of injured patients and provide feedback (biofeedback)**
  - Restore normal function.

Isaac Newton’s “3 Laws of Motion”

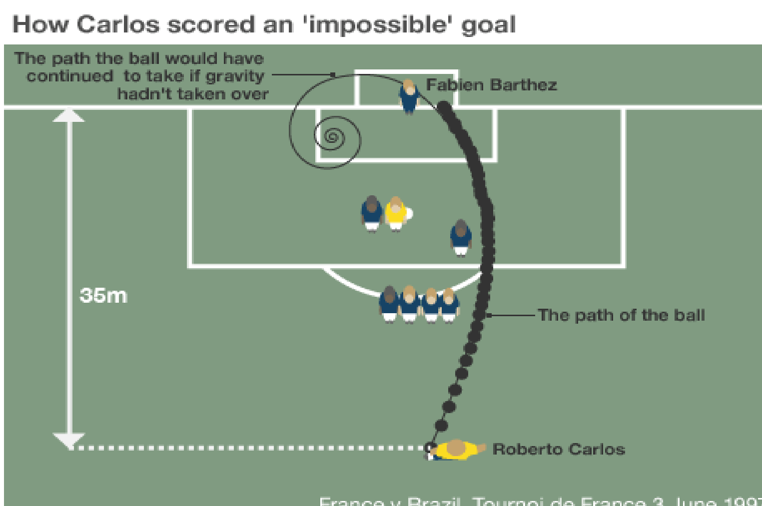
- **The Law of Inertia**
    - An object at rest tends to stay at rest and an object in motion tends to stay in motion (unless an external force is applied eg. friction or gravity).
- **The Law of Acceleration**
    - A force applied to a body causes an acceleration proportional to the force, in the direction of the force, and inversely proportional to the body’s mass.
    - **F=ma**
- **The Law of Reaction**
    - For every action there is an equal and opposite reaction.

Types of Motion

- **It is important to distinguish between two types of motion:**
- **Linear (or Translational) Motion**
  - Movement in particular direction. Example: a sprinter accelerating down the track.
- **Rotational Motion**
  - Movement about an axis. The force does not act through the centre of mass, but rather is “off-centre,” and this results in rotation. Example: ice-skater’s spin.
  - Most human movements are rotational ie they take place around an axis

Centre of Mass (Gravity)

- **The point on an object where its mass is balanced**
  - The point where that body would balance on a very small base
  - A force applied through the the CoM → Linear motion
  - A force applied at a distance to the CoM → Rotation or Angular motion
- **Important concept when stability is important**



Biomechanical Analysis

- **Seven Principles of Biomechanical Analysis**
- **Grouped into 4 broad categories:**
  1. stability,
  2. maximum effort,
  3. linear motion, and
  4. angular motion.

Biomechanical Analysis

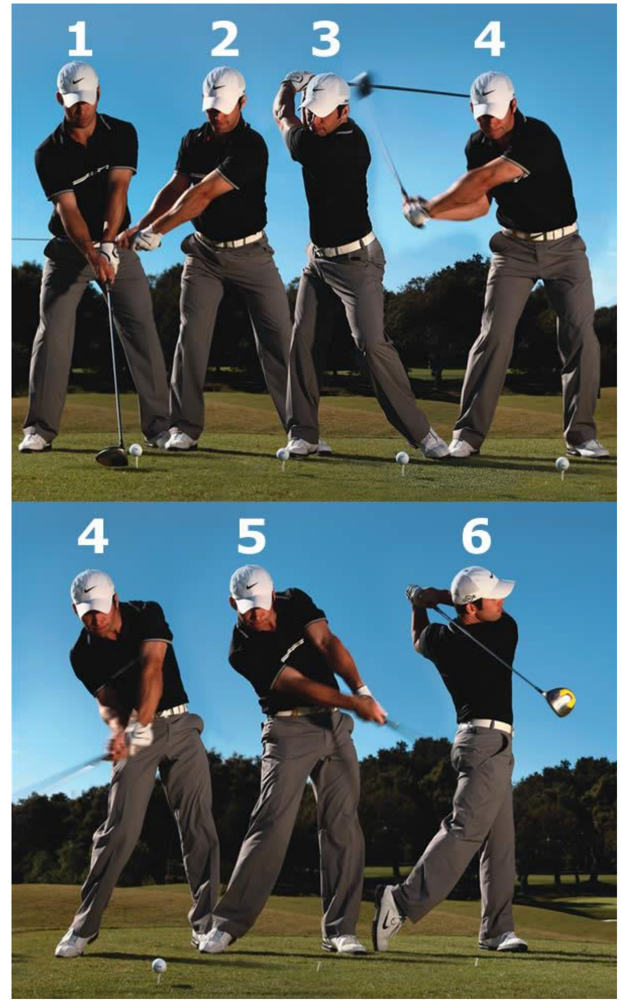
- **STABILITY**
- **Principle 1:**
  - The stability increases
    - Lower center of mass
    - Larger base of support
    - Closer the center of mass to the base of support
    - Greater mass
  - Examples:
    - Sumo wrestling
    - Wrestling
    - Gymnastics
      - Is this position stable? Why?

Unstable Balance

- **Sometimes athletes need to be balanced but ready to move quickly i.e. unstable**
- **Examples**
  - Sprint start
  - Receiving serve in tennis
  - Swim start
    - What makes this unstable?

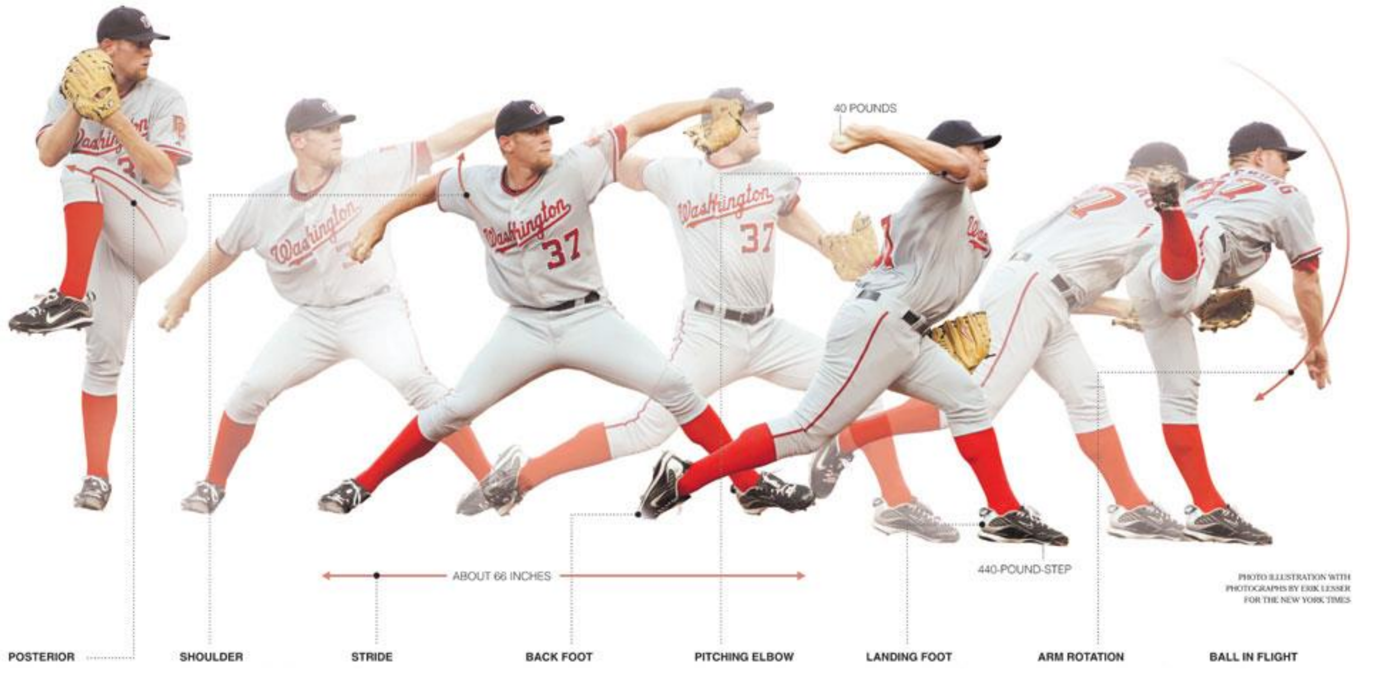
Biomechanical Analysis

- **MAXIMUM EFFORT**
- **Principle 2:**
  - The production of **maximum force** requires the use of all possible joint movements that contribute to the task's objective.
  - Examples:
    - Bench press
    - Sprint start



Biomechanical Analysis

- **MAXIMUM EFFORT**
- **Principle 3:**
  - The production of **maximum velocity** requires the use of joints in order
    - From largest to smallest.
  - Examples:
    - Pitch a baseball
    - Hitting a golf ball



Biomechanical Analysis

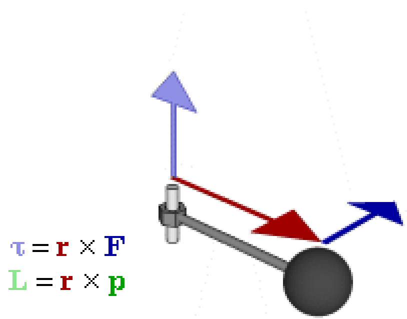
- **LINEAR MOTION**
- **Principle 4:**
  - The greater the applied impulse, the greater the increase in velocity.
    - a = F/m
    - Range of Motion (ROM) important
    - Example:
      - Spiking a volleyball

Biomechanical Analysis

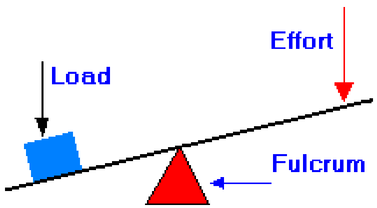
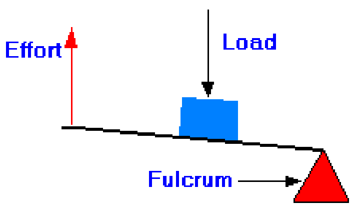
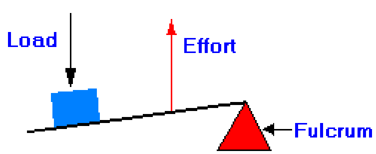
- **LINEAR MOTION**
- **Principle 5:**
  - Movement usually occurs in the direction opposite that of the applied force.
    - Affected by gravity and other forces
  - Examples:
    - Basketball
    - Kicking

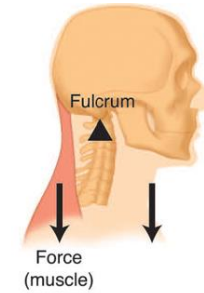
Biomechanical Analysis

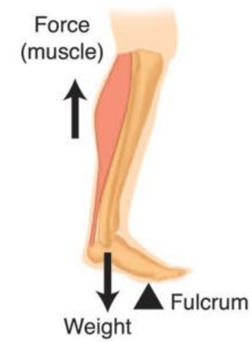
- **ANGULAR MOTION**
- **Principle 6:**
  - Angular motion is produced by the application of a force acting at some distance from an axis, that is, by torque.
  - Torque (or moment)
    - $\tau = r \times F = |r||F|\sin(\theta)$
  - Example:
    - Diving

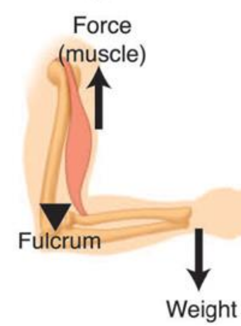


Levers

Class	Illustration	Examples
First	The fulcrum lies between the effort and the resistance  Class 1 Lever	Less force See saw Crowbar Hammer pulling out a nail
Second	The resistance lies between the fulcrum and the point of effort  Class 2 Lever	Less force Wheelbarrow Opening a door by the handle Rowing a boat
Third	The effort lies between the resistance and the fulcrum  Class 3 Lever	More force, more speed Biceps curl Most limbs of the body





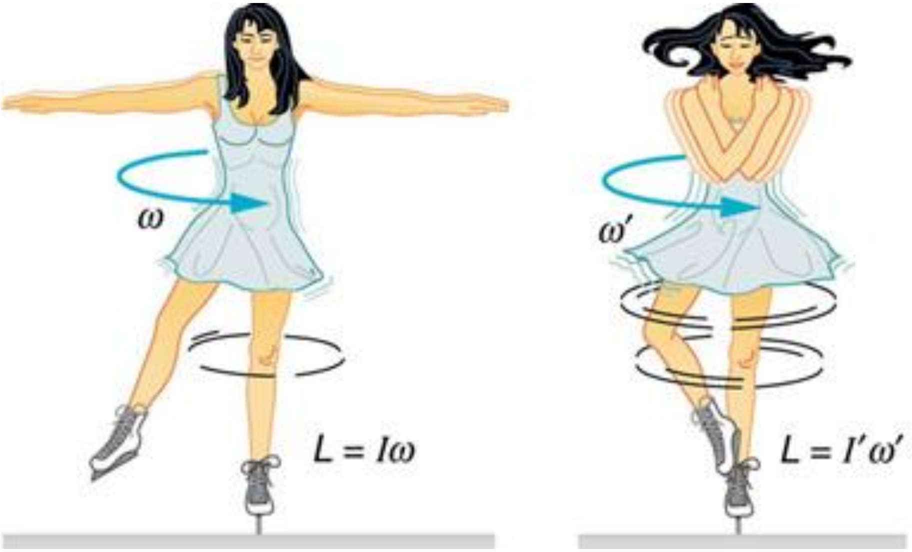


Biomechanical Analysis

- **ANGULAR MOTION**
- **Principle 7:**
    - The principle of conservation of angular momentum
        - Angular momentum is constant when an athlete or object is free in the air
        - Once an athlete is airborne, he or she will travel with constant angular momentum.
- **Linear motion**
    - Force moves a body
    - $F = ma$
    - If no force is applied, momentum is conserved
    - $p = m v$
- **Angular motion**
    - Torque causes a body to spin
    - $\tau = F \times r = I a$
        - a: rotational acceleration ($\Delta\omega/\Delta t$)
        - I: rotational inertia, or moment of inertia
        - $I \propto m r^2$
    - If no torque is applied, angular momentum is conserved
    - $L = I \omega \propto mr^2 \omega$

Examples of Conservation of Momentum

- **Ice-Skating**
  - The ice-skater begins to spin with arms spread apart then suddenly brings them closer to the body.
  - The skater's spin (angular velocity) increases.
  - Explanation
    - When a figure skater draws her arms and a leg inward, she reduces the distance between the axis of rotation and some of her mass → reduces her moment of inertia
    - Angular momentum is conserved → rotational velocity must increase to compensate.

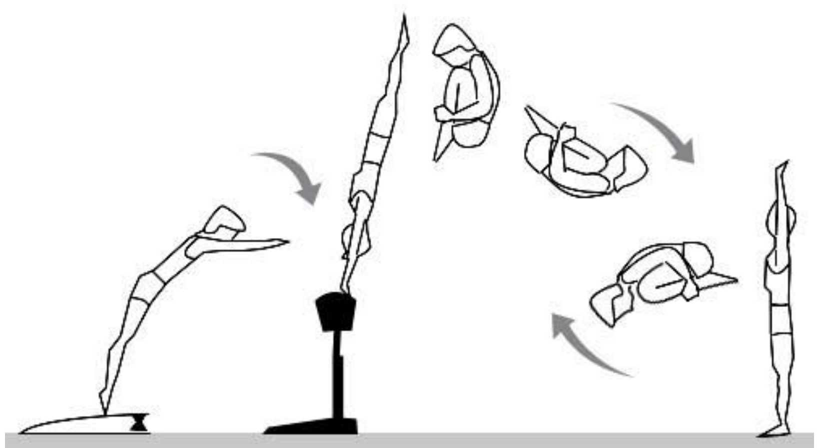


Examples of Conservation of Momentum

- **Diving**
  - After leaving the high diving board, the diver curls tightly and then opens up just before entering the water.
  - By opening up before entry, the diver increases the moment of inertia → slows down the angular velocity.

Examples of Conservation of Momentum

- **Gymnastics**
  - By opening up, the gymnast increases the moment of inertia (radius of rotation), thereby resulting in a decrease in angular velocity.

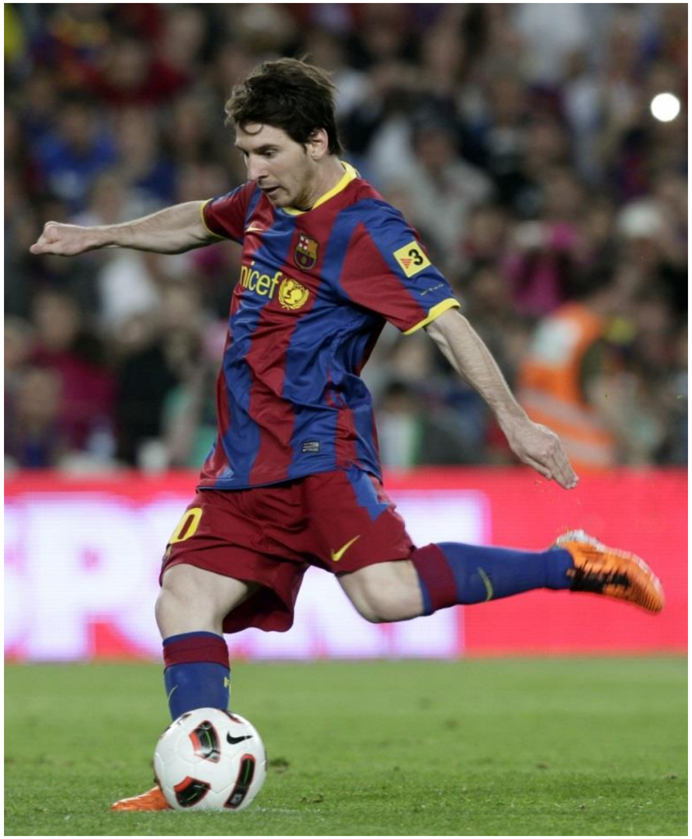


Conservation of Energy

- **The conservation of energy principle**
  - Energy can never be created or destroyed, but can only be converted from one form to another

Elements of Kinesiology

- **Five Phases of a Sport Skill**
  1. Preliminary Movements
  2. Backswing/Recovery
  3. Force Producing Movements
  4. Critical Instant
  5. Follow-Through



- **Used to bring a skill down into smaller parts**
  - Helps coaches to detect and correct errors
  - Key Points are “look fors” that coaches use to produce ideal mechanics / performance

Five Phases of a Sport Skill

Preliminary Movements

- **Key Points**
  - Pick a Target
  - Open stance
  - Hold Ball with Opposite Hand
  - Hold the Ball at Waist Height
  - Eye on the Ball

Five Phases of a Sport Skill

Backswing/Recovery

- **Key Points**
  - Eye on the ball
  - Maintain good posture
  - Large last step
  - Ankle locked

Five Phases of a Sport Skill

Force Producing Movements

- **Key Points**
  - Eye on the ball
  - Maintain good posture
  - Largest muscles to the smallest
  - Use arm for balance
  - Open the hips up

Five Phases of a Sport Skill

Critical Instant

- **Key Points**
  - Eye on the ball
  - Contact with hardest part of the foot
  - Lock your kicking foot upwards
  - Let ball fall below knee height
  - Lock your leg

Five Phases of a Sport Skill

Follow-Through

- **Key Points**
  - Be smooth and fluid
  - Foot carries on towards target
  - Eyes follow ball to target

Elements of Kinesiology

- **Why aren't there more robots walking on two legs?**
  - Because it's REALLY difficult!!!
- **Dynamic Walking**
  - Hundreds of specific and well coordinated movements
  - Almost all joints involved from head to toes
  - Every step involves not only pushing the body forward but also keeping balance
    - When we walk, is like loosing our balance and falling forward
    - Just before loosing our balance, we put one leg forward to support our body
- **Running**
  - It's even more difficult since there are moments when both legs are airborne!

Honda Asimo

- The best biped robot