Why study gait?

- It is a key activity of daily living
- It is an excellent functional test of many systems
  - It involves the interaction of multiple joint movements
  - It is dynamic
  - It is a test of sensory-motor integration
  - It requires adaptation
- Provides insight:
  - Surgical decision making, prosthetic design, orthotic design, rehabilitation strategies, objective tracking of progress, FES, robotics, and artificial intelligence

Motivational Questions:

- Can we determine what the muscles (& other tissues) are doing and why, without cutting open the body?
- Can differences from one side of the body to the other tell us what is wrong or help make decisions on treatment?
- Can differences from “normal” gait tell us what is wrong or help make decisions on treatment?
- Can we assess treatment outcomes & track progress?
- What measurement instruments help us to answer these questions?
- If so, which are best, and which are best for the physical therapist?
- What is the physical therapist’s role?

Web Site

http://manip.smpp.nwu.edu/jim/kinesiology

- Lecture slides
- Links to internet resources
- Animated Examples
Gait goals

Gait is Variable.
This arises from competing goals:

- **Progression:** Safely move the center of mass (CM) forward; turn when necessary, maintain an oscillatory pattern.
- **Support:** Keep upright, maintain balance, avoid collapse.
- **Obstacle Avoidance and Foot Placement:** Foot clearance. Negotiate your way through the world.
- **Energy Conservation:** "Efficiency:" Use the least amount of energy.
- **Smoothness:** Minimize jerk? (Toffee, Jolly Ranchers & viscoelasticity)
- **Minimize Pain:** Adapt gait to avoid painful forces or motions
- **Stability:** Can you keep walking if shoved or tripped, or if your movements deviate from your plan? Muscles, Feedback (reactive), and feedforward (proactive). (Pencil)
- **Robustness:** Can you withstand a large disturbance? How Big? (Popeye)

History

- Anaximander, 625 BC (Animal motion)
- Pythagoras, 500 BC (Animal motion)
- Aristotle, 350 BC (Animal motion)
- Buanaroti, 1500 (Functional anatomy)
- Da Vinci, 1452-1519 (Functional anatomy)
- Galileo, 1564-1642 (Force)
- Borelli, 1682 (Center of gravity, balance & movement)
- Weber brothers, 1836 (Pendulums, Gait Cycle &Marching)
- Marey, 1873 (Video & Force)
- Muybridge, 1878 (Video)
- Braune and Fischer 1890’s (Inverse Dynamics in Gait)
- Bernstein, 1930’s (Motion analysis, motor variability)
- Elftman, 1938 (Force plates)
- Scherb, 1940’s (EMG)
- Inman, 1940’s - 1950’s (EMG, Normative Gait)
- Bresler and Frankel, 1950’s (Inverse dynamics in Gait)
- Saunders, 1953 (Center of gravity & determinants of gait)

Gait measurement techniques:
"streamlined research" gives patterns & deviations

2.1 Force
2.2 Motion
2.3 Electromyography (EMG)
2.4 Energy Consumption

(Observational Gait Analysis)

Force/pressure measurements

- **Foot switches:** cadence, timing. Cheap (~$5)
- **Glass Plate Views:** Pressure distribution
- **Pressure Plates:** Pressure distribution (common)
  - 50,000 amputations per year, 1/2 are preventable
- **Pressure Insoles:** Pressure distribution inside a shoe
- **Force Plates:** Net Force, Center of Pressure (common)

Sample Pressure Animations

(see website for these)

Motion Measurements

- **Goniometers:** Range of motion
- **Electrogoniometers:** Joint angle at successive instants
- **Conductive Walkway:** Stride length, cadence, velocity, dynamic base, etc.
- **Video Cameras:** Stride length, cadence, velocity, dynamic base, etc.
- **High Speed Video:** stop motion measurements
- **Accelerometers:** Accelerations. Cheap.
- **Gyrosopes:** Change in orientation.
- **3D Marker Systems:** All Possible kinematic measures
- **Electromagnetic field:** All Possible kinematic measures (becoming more common)
- **Global positioning (GPS):** ? All Possible kinematic measures
3D Marker Systems

- "Passive" (reflectors) & "Active" (lights)
- markers on landmarks → joint angles by "connect the dots"

PROBLEM: skin movement artifact

Sample Video Animations

(see website for these)

EMG Measurements

- Noisy & qualitative
- Indicator of when the muscle is active
- Surface EMG (most common):
  - Cheap, easy
  - Difficult to interpret because of cross talk & noise
- Fine Wire and Needle EMG:
  - penetrate skin
  - isolate single muscle
  - Mildly Painful
  - May change behavior

Surface EMG Example

Energy Consumption Measurements

- Heart Rate:
  - Cheap, easy
- O₂ Consumption
  - Better indication of relative metabolic state
- Noisy
- Indicator of overall effort
- Often difficult to detect change because of variability

Kinematics & EMG: Knee

(typical results from a gait lab)
**Gait Cycle Terminology**

- We will define the **Gait Cycle** from foot contact to foot contact of the same leg. (Most define it this way)
- Percent of time for each phase:
  - Stance: 60-62%
  - Swing: 38-40%
  - Gait Cycle: 100%
- As you walk faster, swing increases and stance decreases

**Gait Phase Diagram:**

- Gait cycle is 1 Stride (100%)
- Stance (60 to 62%)
- Swing (38 to 40%)

**PHASES:**
- Double Support Phase
- Single Support Phase

**SUB-PHASES:**
- Initial Contact
- Loading Response
- Midstance
- Terminal Stance
- Pre-swing
- Initial Swing
- Midswing
- Terminal Swing

**EVENTS:**
- Heel strike
- Foot Flat
- Midstance
- Initial Double Support Phase
- Loading Response Phase
- End of Double Support Phase
- Foot Off
- Terminal Double Support Phase
- Heel strike

**Review of Mechanics Terminology**

**Mechanics:** Interaction of forces, motions, deformations, and flow.

**Kinematics:** Movements (position, velocity, acceleration, joint angles, etc.)

**Kinetics:** Forces during movements (joint torque, GRF, etc.)

**Forward Dynamics:** How forces cause movements. We use dynamics to estimate the movements that result from forces and moments. \( a = F/m \).

**Inverse Dynamics:** How movements require forces. We use inverse dynamics to estimate the forces that cause the motions we measure. \( F = ma \).

Most labs use measured forces and measured motions combined to get a best estimate of joint torque and muscle actions.
Observational Gait Parameters

Quantitative variables commonly used when performing observational gait analysis to record what has been seen.

Common Parameters

A. Cadence
   - Avg. adult cadence = 113 steps/min

B. Velocity (cadence multiplied by step length) is the distance covered within a unit of time
   - Avg. adult cadence = 260 feet/min

C. Step length is distance from initial contact of one foot to initial contact of the opposite foot
   - Avg. adult = 2.3 feet

D. Stride length is distance from initial contact of one foot to the initial contact of the same foot at next contact
   - Avg. adult = 4.6 feet

E. Dynamic base (base of support) is the distance between parallel lines intersecting the mid-point of each heel print. Avg. adult = 2-4 inches

F. Line of progression is the line approximating the center point between both feet along the path of progression

G. Foot angle is the angle formed by the intersection of the line of progression and a second line, which is drawn through the midpoint of the heel and the space between the first and second toe
   - Avg. adult = 0-15°