Joint Function
&
GAIT Analysis
Joints

- A joint occurs when bone-end meets bone-end
- Synovial joint
  - Bone ends covered with cartilage
  - Relative large range of motion
  - Surrounded by a capsule filled with synovial fluid
Knee Joint Motion
Joint Function

The ability of a joint to maintain an appropriate functional position throughout an intended range of motion

A stable joint is able to carry required loads throughout normal ranges of motion
Types of movements

- Abduction
- Adduction
- Extension
- Flexion
- External rotation
- Internal rotation
- Flexion
- Extension
Types of movements (cont’d)

**ANKLE**
- Dorsiflexion (Flexion)
- Plantarflexion (Extension)

**TOES**
- Extension
- Flexion

**HINDFOOT**
- Eversion (Valgus) (Abduction)
- Inversion (Varus) (Adduction)

**SUPINATION**
- inversion
- + plantarflexion
- + adduction

**PRONATION**
- eversion
- + dorsiflexion
- + abduction

**FOREFOOT**
- Abduction (Valgus)
- Adduction (Varus)

**FOREFOOT**
- Eversion
- Inversion
Joint Reaction Forces

These forces produced via:

Compression of two articular surfaces
Compressive Forces

Required line of application of joint reaction force

A. Required joint reaction force
B. 
C. 
D. $p$
Joint Contact Forces
GAIT

- Utilizes minimal energy to move COM
- Walking is a highly-coordinated process involving
  - CNS
    - Brain
    - Spinal cord
    - Peripheral nerves
  - MSS
    - Muscles
    - Bones & Joints
Single GAIT cycle

The major events:

- **Stance Phase**
  - Heel Strike
  - Foot Flat
  - Toe Off
- **Swing Phase**
  - Acceleration
  - Deceleration
Stance Phase

- Initial Contact
- Loading Response
- Early Mid Stance
- Late Stance
- Terminal Stance
Swing phase
Single GAIT cycle
Support during GAIT cycle

- **Left Leg**
  - **Left Swing Phase**
  - **Left Stance Phase**
  - **Double support**
  - **Right single support**

- **Right Leg**
  - **Right Stance Phase**
  - **Right Swing Phase**
  - **Right initial contact**
  - **Right toe off**
  - **Double support**

**Time**

- **Left toe off**
- **Left initial contact**
- **Right initial contact**
Ground reaction force
Biomechanics of GAIT Analysis

- Important variables
  - Time
  - Mass
  - Force
  - Centre of gravity
  - Moments
  - Motion
    - Linear
    - Angular
Determinants of GAIT

- Pelvic rotation
- Pelvic obliquity
- Knee flexion in stance phase
- Ankle mechanism
- Foot mechanism
- Lateral displacement of body
GAIT Analysis

- Systemic study of human walking
  - Using *experienced* observers
  - Augmented by *instrumentation*
    - Measuring body movements
    - Body mechanics
    - Activity of the muscles

- Purpose
  - Aid in treatment
  - Helps to improve understanding
Methods of GAIT Analysis

Few of the methods used:

- Visual gait analysis
- Timing the gait cycle
- Direct motion measurement systems
- Electrogoniometers
- Electromyography
- Combined Kinetic / Kinematic systems
Abnormal GAIT Patterns

- Anterior trunk bending
- Posterior trunk bending
- Lateral trunk bending
- Increased lumbar lordosis
- Circumduction
- Steppage
The End
Pelvic rotation
Pelvic obliquity

Hip vertical movement

Trunk vertical movement

Double

Stance leg

Single

Swing leg

Double
Knee flexion in stance phase, Ankle mechanism, Foot mechanism
Lateral displacement of body
Anterior trunk bending
Posterior trunk bending
Increased lumbar lordosis
Circumduction

Stance foot

Swing foot
Steppage
Visual gait analysis

- Depends on the skill of observer
- Subject should be observed from different sides to observe gait abnormalities
- Minimum length to be walked = ~10-12 m
- Compare range of motion at joints during walking with those observed on examination plinth
- Cameras may be used
Timing the gait cycle

- Two types
  - Footswitches
    - One switch beneath heel, other beneath forefoot
    - Connected to computer with trailing wire/transmitter
    - Measure timing of stance phase
  - Instrumented walkways
    - Covered with electrically conductive substance
    - Electrical contacts on subject’s shoes
    - Interrupt beams of 2 photoelectric cells to find speed
    - Also measures position of foot contact
Direct motion measurement systems

- Found generally in research labs
- Light string attached to back of belt
- While walking string is pulled through an instrument
  - Uses tacho generator or optical encoder
  - Measures its speed
- Two strings used
  - Measure lateral displacement
Electrogoniometers

- Makes continuous measurements of the angle of a joint
- Potentiometer devices
  - Variable resistor
  - Turning of central spindle
    - Change in electrical resistance
  - Measures joint angle
    - Body is connected to one limb
    - Spindle is connected to the connecting limb
Triaxial goniometers on Hip, knee and ankle
Electromyography

- Measures electrical activity of contracting muscle
- Main methods
  - Surface electrodes
  - Fine-wire electrodes
  - Needle electrodes
- Helps in timing muscle activation
- But cannot measure strength of contraction
Combined Kinetic / Kinematic systems

The gait analysis equipment used in the author's laboratory, with a six-camera kinematic system, two force platforms and an EMG telemetry system.
**Combined Kinetic / Kinematic systems**

- Measurements in 2D or 3D
- Measures
  - Displacements
  - Velocities
  - Accelerations
  - Position and orientation of body segments
  - Angles of joints
- Measure positions of markers at 50 Hz (20ms intervals)
- Uses many of the previous mentioned measurement systems
  - Electrogoniometers
  - Visual methods like videos
  - Force platforms, etc