Introduction to Human Walking & Clinical Gait Analysis

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Motion & Gait Analysis Lab
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Teaching Points

• Phases of the Gait Cycle
• Primary Muscle Actions during Gait
• Common Gait Disorders & Treatments
Motion Analysis at Stanford
Edweard Muybridge & Leland Stanford 1878
Muscle Activity During Gait
Initial Contact

- Heel First Contact
Toe Walking
Diplegic Cerebral Palsy
Mid-Stance

- Controlled Tibial Advancement
3 Foot & Ankle Rockers

Terminal Stance

- Locked Ankle
- Heel Rise
- Trailing Limb
Calf Muscle Weakness

No Fixed Ankle or Heel Rise
Spastic Cerebral Palsy
Swing Phase

- Peak knee flexion in initial swing
- Ankle dorsiflexion to achieve foot clearance
Gait Analysis

- Video
- Kinematics and Kinetics
- Dynamic EMG
- Postural Balance
- Energy Expenditure
Diplegic Cerebral Palsy
Kinematics & Kinetics

- Kinematics: 3-D Joint Motion
  - 8 Digital Motion Capture Cameras Record Position of Light Reflective Markers

- Kinetics: Forces Passing through Joints
  - Force Plate Embedded in Floor Records
  - Ground Reaction Force Vectors
Kinematics

- Nearly normal hip motion
- Increased knee flexion at IC and stance
- Reduced peak knee flexion in swing
- Increased plantar flexion in terminal stance
- Internally rotated foot progression
Musculoskeletal Computer Models of Gait

Computer models are generated from gait kinematics (joint motion) and kinetics (joint forces) and reveal the biomechanical features that influence gait.

Surgical Planning Based On Muscle-Tendon Lengths

The changing muscle lengths during gait are calculated using the computer model. Muscles that are too short and limit gait can be identified and selected for treatment.
Kinetics

- Normal ankle plantarflexor moment peaks in terminal stance

- Increased plantar flexor moment in loading “double bump” with increased plantar flexion at IC

- Decreased plantar flexor moment in terminal stance with loss of forefoot rocker
Dynamic EMG During Gait

- Footswitch or Markers
- Electrodes
  - Surface
  - Fine Wire
- Interpretation

<table>
<thead>
<tr>
<th>Normal Electromyographic Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hopsoas</td>
</tr>
<tr>
<td>Sartorius</td>
</tr>
<tr>
<td>Rectus Femoris</td>
</tr>
<tr>
<td>Adductor Brevis</td>
</tr>
<tr>
<td>Vastus Intermedius</td>
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<tr>
<td>Vastus Medialis</td>
</tr>
<tr>
<td>Gluteus Maximus</td>
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<tr>
<td>Semimembranosus</td>
</tr>
<tr>
<td>Gluteus Minimus</td>
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<tr>
<td>S.I.H. Biceps Femoris</td>
</tr>
<tr>
<td>Extensor Digitorum Longus</td>
</tr>
<tr>
<td>Gastrocnemius</td>
</tr>
<tr>
<td>Popliteus</td>
</tr>
<tr>
<td>Flexor Hallucis Longus</td>
</tr>
<tr>
<td>Peroneus Longus</td>
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</tbody>
</table>

![Graph showing normal electromyographic data](image)
Dynamic EMG & Kinematics
Postural Balance

- Force Plate Center of Pressure
- Postural Sway with Eyes Open / Closed
Energy Expenditure

Energy Expenditure Index

![Graph showing Energy Expenditure Index (EEI) vs. Walking Speed (m/min)].

**EEI** = \( \frac{\text{Walking Heart Rate} - \text{Resting Heart Rate}}{\text{Walking Speed}} \)

- Patient
  - Before Surgery
  - After Surgery

Range of Normal Values
Pathologic Gait
Neuromuscular Conditions

- Equinus
- Equinovarus
- Pseudo equinus (knees bent, ankles at neutral, forefoot contact)
- Jumped (knees bent, ankles true equinus)
- Crouch (knees bent, ankles dorsiflexed)
- Stiff–knee gait
Pathologic Gait
Musculoskeletal Conditions
Polio, Dislocation, Arthritis, Muscular Dystrophy

- Pain
- Muscle weakness
- Structural abnormalities (joint instability, short limb)
- Loss of motion
- Combinations of above
Antalgic Gait

Painful Gait

• Any gait that reduces loading on an affected extremity by decreasing stance phase time or joint forces

• Examples
  – “stone in your shoe”
  – Painful hip, knee, foot, etc
Thank You