Gait Lab Testing and Treatment Planning in Brain Injury

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Gait Laboratory Services

Scripps Memorial Hospital Encinitas
Rehabilitation Center

What do we associate this technology with?

- Movies
  -Avatar

- Video Games
  - NHL 2010

- And Finally.....GAIT

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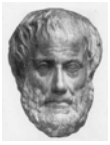
Learning Objectives

1. Be able to Identify patients appropriate for gait analysis
2. Have a good understanding of the normal gait cycle
3. Be familiar with the capabilities and technology in a gait and motion analysis lab
4. Able to efficiently design a treatment plan focused on root cause of the walking abnormality

A Brief History

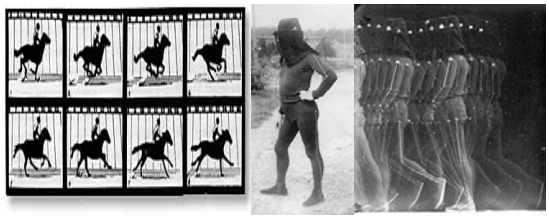


- **Aristotle** (384–322 BCE) can be attributed with the earliest recorded comments regarding the manner in which humans walk
- **Da Vinci** (1452-1519) described the mechanics of standing, walking, and jumping as well as advancing the field of human anatomy.
- **Borelli** (1608-1679) wrote *On the Motion of Animals*, describing muscular movement and body dynamics.

Modern History

- Before computerization, physicians relied on watching patients walk or analyzed film or photographs to identify gait abnormalities
- **Edward Muybridge** was a pioneer in 1878 with the advent of photography
- Attached a series of 12 cameras to automatically and sequentially fire and record the gait of a horse

- For the first time Muybridge was able to capture several images that could be mounted together to represent a cycle of motion



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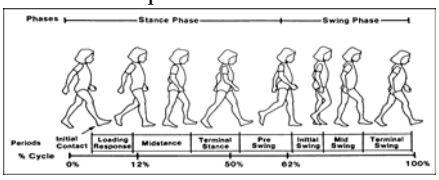
- **Verne Inman** (1905-1980) developed a research program at Universities in Berkeley and San Francisco directed at amputees who were returning from World War II (1944–1947)
- Moved the science of gait analysis forward by developing the foundation for kinesiological electromyography (KEMG), 3-D force, and energy measurements in the study of walking in amputees

- **David Sutherland** (1923–2006) introduced the concept of *computerized* motion analysis with the technical assistance of aerospace engineers in the 1960s
- Three-dimensional motion analysis became the hallmark of Dr. Sutherland's lab at Children's Hospital, San Diego.
- Devised surgical techniques to treat children with such conditions as cerebral palsy and spina bifida

- **Jaquelin Perry** (1918-present) helped develop observational gait analysis techniques dividing gait into distinct phases



- Used 3D motion analysis, KEMG, and force biofeedback devices in the PK lab at Rancho Los Amigos Rehabilitation Center to improved prosthetic and orthotic devices for patients post stroke

Why Analyze Gait?

1. Clinical uses:
- To identify the root cause of walking abnormalities
- To improve treatment planning
- To determine effectiveness of a treatment plan and decide if further treatment is necessary

2. Research:
- Track Disease and disability
- Develop and investigate new and old treatments
- Improvement of body mechanics

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Literature Support

- Exclusively dedicated to gait and motion analysis research
- Numerous publications in: Archives of Physical Medicine and Rehabilitation, Clinical Orthopedics, and the Journal of Pediatric Orthopedics

Recent Examples

- Williams G., Morris M., Schache A., McCrory P. (2009). Observational gait analysis in traumatic brain injury: Accuracy of clinical judgment. *Gait & Posture 29 (2009) 454-459*

  -**OGA had low accuracy with a high percentage of disagreements (50% on average)**
  -**Inter-item correlations were low even for experienced clinicians**
  -**Suggests high inaccuracy rate could potentially have a negative impact on clinical decision making**

- Ounpuu, S., Bell K., DeLuca P. (2008). The "Birthday Syndrome" vs. the single event multilevel surgical approach: a comparison of financial costs. *Proceedings of the 13th Annual Gait and Clinical Movement Analysis Society*, 2008, 160-161.

  -found average cost of a single event multilevel surgery was cut in ***half*** by using gait analysis when compared to a staged approach

- Wren T.A.L., Kalisvaart, M., Ghatan, C., Rethlefsen, S.A., Hara, R., Sheng, M., Chan, L.S., Kay, R.M., (2009). Effect of pre-operative gait analysis on costs and amount of surgery. J Pediatr Orthop. 29, 558-563, 2009.

  -found ***three times*** more surgeries per person per year for ambulatory patients with cerebral palsy who did not have gait analysis testing prior to their initial surgery

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Who Is Appropriate?

Patient's with:

- Brain Injuries
- Hemiplegia post stroke
- Parkinson's Disease
- Cerebral Palsy
- Osteoarthritis
- Total Joint Replacements
- Pre muscle or tendon transfers
- Pre antispasmodic treatment
- Orthotic prescription
- Prosthetic prescription
- Pre Osteotomy

Anybody who has trouble walking

Who Is Appropriate?

- Assistive devices accepted:

-Single Point Cane

-Front Wheel Walker….etc.

- Braces accepted:

-Ankle Foot Orthotic

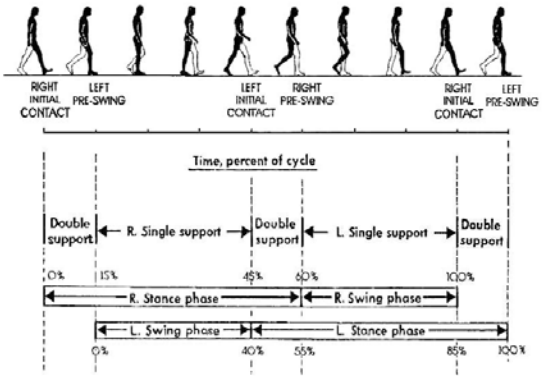
-Knee Ankle Foot Orthotic

-Hand Splints….etc.

Who Is *NOT* Appropriate?

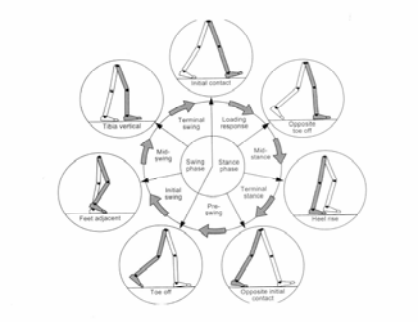
- Must be able to walk!
  -No Max Assist patients please
- Must be cognitively aware to agree to the study and be able follow simple directions

NORMAL GAIT



The Gait Cycle

- Each leg repeats the same pattern of movement



Phases Of Gait

- Divided into 2 phases:
  1. Stance
     - -Initial Contact - Loading response
     - - Mid Stance - Terminal Stance
  2. Swing
     - -Pre Swing - Initial Swing
     - - Mid swing -Terminal Swing

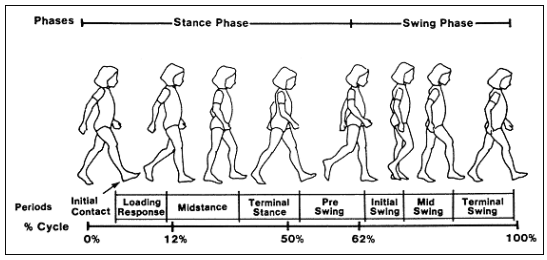
Stance Phase

1. Initial Contact (0% gait cycle)
   -When the Foot makes contact with the ground

2. Loading Response (0-12% gait cycle)
   -Weight transferred to limb

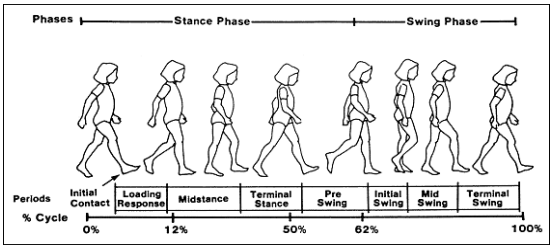
3. Mid Stance (12-31% gait cycle)
   -The body progresses over a single stable limb

4. Terminal Stance (31-50% gait cycle)
   -The body moves ahead of the limb and weight transferred to forefoot



Swing Phase

1. Pre-Swing (50-62%)
   -Unloading of limb with weight transferred to contralateral limb
2. Initial Swing (62-75%)
   -Foot comes off floor while the thigh advances
3. Mid Swing (75-87%)
   -Foot clears floor, tibia is vertical while the knee extends and thigh advances
4. Terminal Swing (87-100%)
   -Knee extends, limb prepares for foot contact



Pathological Gait

Common Deviations

- Abnormal foot contact
- Foot Slap
- Foot Drop
- Inadequate dorsiflexion control
- Contralateral vaulting
- Excessive knee extension/flexion (crouch gait)
- Knee extension thrust
- Hip hiking
- Pelvic retraction
- Abnormal hip rotation
- Contralateral hip drop (Trendelenburg)
- Circumduction
- Increased lumbar lordosis
- Post/Ant trunk lean
- Excessive trunk side bend

Equipment

What's in the Lab?

- Vicon MX System for the Life Sciences
  - -High Speed Giganet
- Other motion capture companies
  - -Qualysis
  - -Motion Analysis
  - -BTS
  - -PTI

- Near Infrared cameras

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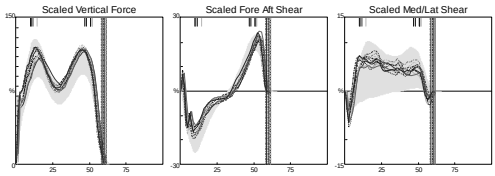
- Force Plates
  -Use Piezoelectric force transducers

- Measures 3 orthogonal components of the Ground Reaction Force (GRF)



- Use inverse dynamics to calculate joint torques/power

- Kinesiological Electromyography system (KEMG)
  -8 Channels
  -Surface and Fine Wire capabilities

- Measures electrical activity of muscle including On/Off times
- Each group of muscles fire in a sequential pattern at specific points in the gait cycle
- Can determine if deviation caused by overactive vs. underactive muscle action

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Video Analysis

- Systematic approach for position and motion of:
  - Pelvis and Spine
  - Hips
  - Knees
  -Ankles
- Look for specific gait abnormalities (i.e. stiff knee gait)
- Advantages:
  -Can perform slow motion visual gait analysis
  -Provides a permanent record
  -Gait pattern can be viewed repeatedly
  -Quality control to match 3D data to 2D data

Gait Characteristics Measured In Lab

1) Kinematics
   -Joint angles
   -Angular velocity

2) Kinetics
   -Ground Reaction Force (vertical direction)
   -Fore/Aft Sheer
   -Medial/Lateral Sheer
   -Joint Moments (torque)

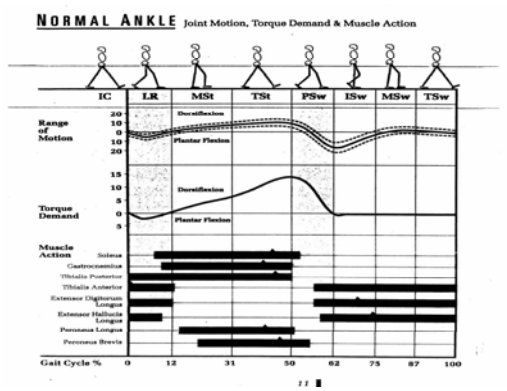
Gait Characteristics Measured In Lab

3) Spatio-temporal Parameters
- Cadence (steps/min)
- Speed (m/s)
- Stride Length (m)
- Step Length (m)

4)Kinesiological Electromyography (KEMG)
- Pattern of muscle activation
- On/Off times

Gait Analysis Protocol

1. Patient history of current condition
2. Perform Physical Exam
   -Strength, ROM, Spasticity…etc.
3. Video recording of subject walking
   -normal gait front and back, and side
4. Record 3D Kinetics/Kinematics
5. Interpret results and make recommendations



Putting it all together

History/Physical Exam

Computerized Motion Data

Gait Laboratory PT

Neurologist/Orthopedic Surgeon

Orthotist

Treating PT

Best Treatment

Case Study

Mr. CM

-19 year old male injured in an MVA 4/2011

-High school senior athlete and pianist

-Sustained TBI and fractures to C7, left acetabulum, and left toe

-Began therapy 7/2011

Initial Gait

- See Video/Polygon VSK

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Impairments Affecting The Gait Pattern

1) Pelvic obliquity with left retraction throughout
   -tight Left L/S paraspinals, oblique, quadratus lumborum….etc
2) Left quadriceps, hamstring, gastrocnemius spasticity
3) Left gluteus medius/maximus and gastrocnemius weakness
4) Left hip flexor weakness and tightness

Treatment/Recommendations

1) Correct pelvic obliquity and timing for proper COM displacement facilitating forward progression
2) Strengthening of the Left glut med/max and gastrocnemius for stance stability
3) Aggressive stretching of the hip flexors, adductors, and hamstrings to facilitate stride length
4) Gait training with focus on pelvic protraction at initial contact and hip and knee flexion in swing

HEP

Chart Copy For:

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Side Plank - Beginner
Perform 1 set of 10 Repetitions, once a day.

AROM thoracic/lumbar rotn diag on Ball
Perform 3 sets of 20 Repetitions, once a day.
Use 10 lbs Ball.
Rest 1 Minute between sets.
Perform 1 repetition every 4 Seconds.

Stretch lumbar sidebend kneel w/ball
Perform 1 set of 4 Repetitions, twice a day.
Use Ball.
Hold exercise for 20 Seconds.

Stretch Iliocostalis stand
Perform 1 set of 4 Repetitions, twice a day.
Hold exercise for 20 Seconds.

AROM lumbar rotn sidelying knee bent uni
Perform 3 sets of 20 Repetitions, once a day.
Rest 1 Minute between sets.
Perform 1 repetition every 4 Seconds.

Resist lumbar sidebend w/wt
Perform 3 sets of 10 Repetitions, once every other day.
Use 10 Lbs.
Rest 1 Minute between sets.
Perform 1 repetition every 4 Seconds.

List of Improvements

- Spatio-temporal Parameters
  - -Velocity improved by 4%
  - -Stride length improved by 4%
  - -Left step length improved by 3%
- EMG
  - -Left tibialis anterior timing normalized

- Kinematics
  - -Left pelvic retraction normalized throughout the gait cycle facilitating forward progression (100% improvement)
  - -Pelvic obliquity reduced by 35% at initial contact and 36% in mid stance, but still has the Left side elevated compared to the Right
  - -Left pelvic elevation reduced by 55% in swing (less hip hike/Trendelenburg but still present)
  - -60% increase in Left hip extension during terminal stance

- Kinematics (cont)
  - -Left hip ab/adduction normalized (100% improvement)
  - -All kinematic timing for the Right hip, knee, and ankle improved by 8-10% of gait cycle
  - -Excessive Right knee flexion reduced by 30% in stance, and 13% in swing
  - -Left knee flexion improved by 11% in mid swing
  - -Left external foot progression (out-toeing) reduced by 23% in stance
  - -Trunk: Left side bend reduced by 40% during loading response and in terminal swing

Post Test Improvement

- See Video/Polygon VSK

Review of Learning Objectives

1. Be able to Identify patients appropriate for gait analysis

➢ Improve walking ability for patient's with:

- Hemiplegia post stroke
- Parkinson's Disease
- Cerebral Palsy
- Osteoarthritis
- Total Joint Replacements
- Pre muscle or tendon transfers
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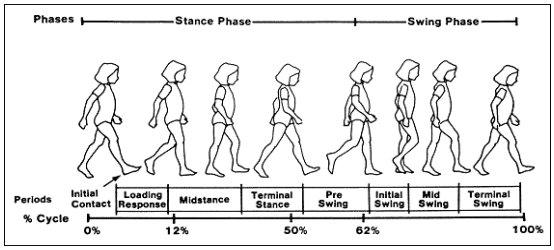
2. Have a good understanding of the normal gait cycle



3. Be familiar with the capabilities and technology in a gait and motion analysis lab

4. Able to efficiently design a treatment plan focused on root cause of the walking abnormality

- Based off: physical exam + computerized data + video/visual analysis + clinical expertise + multidisciplinary communication = Best Practice

Special Thanks

- Rebecca Askew PT, MPT
- Suzanne Carr PT, DPT
- CM and his family for their patience and cooperation