Normal Gait & Gait analysis

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Normal Walking

- Repetitive sequence of limb movement

- Purpose
  - Safely advance the body with minimum energy expenditure
Understanding of Normal Gait

- Enable to understand pathologic gait
- Enable to treat the pathology accurately
FIVE MAJOR ATTRIBUTES

- Standing Stability
- Foot clearance during swing
- Appropriate pre-positioning of foot
- Adequate step length
- Energy conservation
Gait Analysis

- Sagittal plane
- Coronal plane
- Transverse plane
Methods of Gait Analysis

- Observational analysis
- Other conventional analysis
- Modern analysis
Observational Gait Analysis

- By **naked eye** or **video** observation

- **Problems**
  - Eye frame: only about 1/16 of a second
  - Could not observe multiple joint simultaneously
  - Could not differentiate the primary from compensatory
  - Could not evaluate the kinetics of the pathology
Modern Gait Analysis

- 3-dimensional analysis
- Objective data
- Power analysis
- Muscle action analysis
- Energy consumption
Modern Gait Analysis System

- **Optical Tracking** System
  - Video camera
  - CCD (Charge Coupled Device) Camera

- **Dynamic EMG Monitoring** devices

- **Pressure** Measurement
  - Pedobarogram
  - Force plate

- **Energy Consumption** Detection Devices
Gait Laboratory
CCD Camera

- CCD (charge coupled device)
- Camera
  - Motion analysis
- Digitalize the image
Markers

- Reflective tape on surface
- 3 markers in one segment
- Variety size
EMG (electromyography)

- Surface EMG
- Noraxon TeleMyo 2400R
**Force Plates**

- A kind of strain gauge
- AMTI (Advances Mechanical Technology, Inc.)
Process of Gait Analysis

- Measuring & P/E
- Marker attachment
- Static data capture
- Dynamic data capture
- EMG
- Computer process
- Data print out
Kinematic Data
Kinetic Data
Dynamic EMG
DEFINITIONS & TERMS
THE GAIT CYCLE -- WALKING
THE GAIT CYCLE -- WALKING

- Stance (60%)
  - Double stance
    - DS (Double Stance)
    - LR (Loading Response)
    - MST (Mid Stance)
    - TST (Terminal Stance)
  - SS (Single Stance)

- Swing (40%)
  - Double stance
    - ISW (Initial Swing)
    - MSW (Mid Swing)
    - TSW (Terminal Swing)
  - Toe-Off

- Initial Contact
- Loading Response
- Terminal stance
- Initial Swing
- Terminal Swing
- Pre swing
- Mid swing
STANCE PHASE

IC  LR  MST  TST  PS

1st Rocker

2nd Rocker

3rd Rocker
THE GAIT CYCLE -- RUNNING

Stride (100%)

Stance < 50%
Power Absorption
MST

Power Generation

Swing > 50%
DF
ISW
MSW
TSW

DF

Toe-Off

IC

IC
Temporal measurement

- Step length
- Stride length
- Cadence
- Walking velocity
Step & Stride length
No. of steps / minutes
Walking velocity

- meter / minute or cm / minute
- constant after 5-6 yrs
- $= \text{step length} \times \text{cadence}$
Development of Gait

- **1Y**
  - Wide based
  - Stiff knee
  - Toe-heel

- **3Y6M**
  - Adult pattern:
  - Heel-toe
  - Normal knee

Maturation
Development of gait after 3Y6M

- Cadence: ↓
- Step length: ↑
- Velocity: becomes constant
MOMENT OF FORCE

- Moment produce angular acceleration
- Force x Distance from axis
- Unit: Newton-meter
INTERNAL VS EXTERNAL MOMENTS

Internal Moment (muscle force) = 2F

External Moment (GRF) = F

D = 2D
ANKLE MOMENTS

1st rocker

G.R.F.

3rd rocker

G.R.F.
ANKLE MOMENTS (Newton - meters)

- Plantarflexor
- Dorsiflexor

% Gait Cycle

0 25 50 75 100

T.O.

0 2.0 1.0

1st 2nd & 3rd
Modes of Muscle Action:

- **Eccentric** (lengthening under tension)
  - Decelerators and shock absorbers work

- **Isometric** (tension, without length change)
  - Stabilizers work

- **Concentric** (shortening under tension)
  - All accelerators work in this mode
Joint Power

- **Moment of force** \(\times\) **Angular velocity**
  - Units = watts / kg

- **Concentric** contraction
  - Power generation

- **Eccentric** contraction
  - Power absorption
ANKLE JOINT POWER

ANKLE ROCKERS

1st

2nd

3rd
ANKLE JOINT POWER

generation

watts / kg

absorption

A1

A2

% Gait Cycle
LOADING RESPONSE

CONTROL OF FIRST ROCKER
LOADING RESPONSE

CONTROL OF FIRST ROCKER
MIDSTANCE

CONTROL OF SECOND ROCKER
MIDSTANCE

CONTROL OF SECOND ROCKER
TERMINAL STANCE

CONTROL OF THIRD ROCKER
TERMINAL STANCE

Gastrocsoleus

CONTROL OF THIRD ROCKER

GRF
THE ANKLE

STANCE PHASE

IC  LR  MST  TST  PS

Dorsiflex
Plantarflex

1ST ROCKER
2ND ROCKER
3RD ROCKER
SWING PHASE
THE ANKLE

SWING PHASE

Dorsiflex
Plantarflex

1ST ROCKER
2ND ROCKER
3RD ROCKER

STANCE SWING

Anterior Tib.

IS MSW TSW

SWING PHASE
THE ANKLE

KINEMATICS

KINETICS

2
Plantarflexion
JOINT
MOMENT
N - M / kg

3
Concentric
JOINT
POWER
(Watts / kg )

3
Eccentric

0

0

0.21 ± 0.09

-0.10 ± 0.05

% GAIT CYCLE

% GAIT CYCLE

% GAIT CYCLE
THE ANKLE

**CONTRACTION TYPE**
- CONCENTRIC
- ECCENTRIC
- ISOMETRIC

**MONO-ARTICULAR**
- SOLEUS
- ANT. TIBIALIS

**BI-ARTICULAR**
- GASTROCNEMIUS
THE KNEE

Loading Response
THE KNEE

Loading Response
THE KNEE

STANCE PHASE

IC LR MST TST PS

Flex. 20° 62°

TO LR IS
THE KNEE

Mid-stance Phase
THE KNEE

STANCE PHASE

IC LR MST TST PS

Flex. 20° 62°
THE KNEE

Terminal-stance Phase
THE KNEE

STANCE PHASE

IC  LR  MST  TST  PS

Flex.  62°

LR  IS

20°
THE KNEE

Pre- & Initial Swing
THE KNEE

Swing Phase
KINEMATICS

THE KNEE

KINETICS

JOINT MOMENT
\[ N - M / kg \]

Extensor
Flexor

JOINT POWER Generation
Absorption

(Watts / kg)

% GAIT CYCLE
Early Stance Phase
THE HIP

STANCE PHASE

IC  LR  MST  TST  PS

Joint Rotation

Flexion

Extension

T.O.  90

5°
P.F.

TST  MSW

-15

-15
THE HIP

Mid- & Terminal Stance Phase
THE HIP

STANCE PHASE

IC LR MST TST PS

T.O. 90 75 5° 45 45
P.F. 30 30 15 15 15

Flexion
Joint Rotation
Extension

TST MSW
The Hip

Pre-swing & Swing Phase
THE HIP

Concentric
Rectus Femoris

Hamstring

Isometric

Eccentric

Eccentric

THE HIP

SWING PHASE
KINEMATIC

THE HIP

KINETICS
MUSCLE

MONO-ARTICULAR

HIP EXTENSORS

HIP FLEXORS

BI-ARTICULAR

HAMSTRINGS

RECTUS FEMORIS

THE HIP

CONTRACTION TYPE

CONCENTRIC

ECCENTRIC

ISOMETRIC

IC L R MS TST PS IS MSW TSW IC

Toe Off

Toe Off

Toe Off

Toe Off
Pelvic Tilt
THE HIP -- CORONAL PLANE

Pelvic Obliquity

Hip Adduction

Down-Up

Ab/Ad
Transverse Plane

Pelvic Rotation

Hip Rotation

Foot Progression (vs. Tibia)

Foot Rotation
3D Modeling Technique
Thank you for your attention !!!