Evaluation of Orthosis Function in Children with Neuromuscular Disorders Using Motion Analysis Outcomes

Sylvia Õunpuu, MSc and Kristan Pierz, MD
Center for Motion Analysis
Connecticut Children's Medical Center
Farmington, Connecticut

NOTE
Please note – we are not including patient photographs in the handout for patient confidentiality reasons.

Purpose
To demonstrate how clinical gait analysis can aid in the understanding of orthosis function and prescription in children and adolescents with neuromuscular disorders.

Objectives
• Be familiar with:
  – basic tools needed to interpret joint kinematic and kinetic data
  – typical and atypical joint kinematic and kinetic patterns
  – the goals of orthosis function in terms of joint kinematics and kinetics
• Understand the clinical utility of incorporating joint kinetic concepts in orthosis prescription and decision-making

Question?
How many people have written the following script?
– Diagnosis: Cerebral Palsy
– Prescription: AFO
Outline

• Terminology
• Methods
• Typically developing
• Case examples – variety of pathologies

Definitions

• Kinematics:
  – Joint and segment motion (degrees) during gait
  – Coronal, sagittal and transverse plane
  – Trunk, pelvis, hips, knees, ankles and foot progression

Definitions

• Joint Kinetics:
  – Description of the forces that cause motion during gait
  – Sagittal and coronal planes
  – Hip, knees and ankles
  – Joint moments and powers

Definitions

• Joint Kinetics
  – Help in the understanding of the cause of gait abnormalities
  – Impact of pathology on forces/loads
• Joint kinetics provide additional understanding for orthosis decision-making and evaluation not possible with joint kinetics

Gait Cycle:

• Period of time from one event (usually initial contact) of one foot to the subsequent occurrence of the same foot
• Represented as 0 to 100% of the gait cycle
• Allows comparison of multiple strides of data

Gait cycle divisions:

• Stance phase (ST):
  – The period in time when the foot is in contact with the ground.
  – In normal gait this represents about 60% of the gait cycle.
• Swing phase (SW):
  – The period in time when the foot is not in contact with the ground.
  – In normal gait this represents about 40% of the gait cycle.
Phases of the gait cycle: (Perry, 1994)

- loading response (LR) / double support 0-10%
- mid-stance (MST) 10-30%
- terminal stance (TST) 30-50%
- pre-swing (PSW) / double support 50-60%
- initial swing (ISW) 60-73%
- mid-swing (MSW) 73-87%
- terminal swing (TSW) 87-100%

Ankle Sagittal Plane Motion

- Angle Definition
  - the relative angle between a line perpendicular to the long axis of the shank and the plantar aspect of the foot
  - as viewed by looking along an axis perpendicular to the shank-foot plane

Ankle Sagittal Plane

Perpendicular to the tibia relative to the plantar aspect of the foot
Knee Sagittal Plane

Femur relative to the tibia

Joint Kinetics

- Help in the understanding of the
  - cause of gait abnormalities
  - biomechanical impact of pathology
  - biomechanical basis for treatment
  - muscles are producing forces
  - muscles that are contracting

1. KINETIC FUNDAMENTALS

What is a “Moment”???

- A moment is a force’s ability to cause the rotation of an object
  - Synonymous with torque
  - Moment = force x distance

Moment

moment = force x distance

Joint Moments

Muscles create moments about joints called “joint moments”

Joint Moment = force (F) x distance (d)

What happens when the quadriceps contract?
Net Joint Moment

- Summation of all the forces acting on a joint to produce joint movement
  - External forces
    - Act upon the body
  - Internal forces
    - Body’s response to external loads

Internal Forces

- Active forces: muscle contractions
- Passive forces: ligaments, muscle/tendon contractures (anything that constrains joint motion)

External forces
- Ground reaction force
- Gravity – segment weight (mass)
- Inertia – segments rotational inertia

Internal and External Forces?

VIDEO

ANKLE – Ground reaction force

GRF

Initial Contact

Moment_{GRF} = F_{GRF} \times d

ANKLE – Force due to mass of segment

F_{weight} \times d

Initial Contact

Moment_{WT} = F_{WT} \times d
Orthosis Evaluation Using Motion Analysis – Part 1

**ANKLE – Muscle force**

- Initial Contact
- Muscle force
- Moment\(_{\text{muscle}}\) = \(F_{\text{muscle}} \times d\)

**Net Internal Moment**

- Net Internal Moment = body’s response to external loads
- Results in desired motion and stability
- Calculated through a process called Inverse Dynamics

**Hip – Knee - Ankle Joint Moments**

(Ontsu et al., JPO, 11:341-349, 1991)

**Typical kinetic patterns – Ankle**

- Note – ground reaction force illustration
- – not complete computation

**Ankle**

- First Rocker
  - Heel initial contact
  - Small dorsiflexor moment
  - Negligible power

**Ankle**

- Second Rocker
  - Weight bearing progresses distally under foot
  - Eccentric ankle plantar flexor activity allows for controlled ankle dorsiflexion
  - Progressively larger ankle plantar flexor moment
  - Negligible power
Ankle

- Third Rocker
- Ankle plantar flexors concentrically contract to provide propulsion
- Large extensor moment and power generation until the end of single stance

Ankle

- Swing
  - Negligible moment power due to small mass of the foot

Examples of Atypical Ankle Moments……..

What abnormal contact pattern does this suggest?

- Sagittal plane ankle moment (3 trials vs. typical)

Resultant Ground Reaction Force

Loading Response  Mid Stance  Terminal Stance

Foot flat initial contact pattern

- Absence of dorsiflexor moment during loading response
- Early and gradual development of a plantar flexor moment
- Normal peak plantar flexor moment in terminal stance
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What abnormal contact pattern does this suggest?

- Sagittal plane ankle moment (3 trials vs. typical)

Resultant Ground Reaction Force

Loading Response | Mid Stance | Terminal Stance

What is “Power”

- Power is the rate at which the net moment is able to rotate the segment
- Power = Moment x Angular Velocity
- Joint power is required to move!
- Provides information about type of muscle contraction
**Power Absorption and Generation**

- an eccentric contraction = power absorption
- a concentric contraction = power generation

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**Hip-Knee-Ankle Powers**

(Oinpuu et al., JPO, 11:341-349, 1991)

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**Ankle**

- First Rocker
  - Minimal power due to minimal ankle motion
- Second Rocker
  - Power absorption with eccentric contract of ankle plantar flexors as the ankle dorsiflexes
- Third Rocker
  - Power generation with concentric contraction of the ankle plantar flexors to provide plantar flexion

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**Test!**

- What would you predict would be the joint moment for this patient? (walking with shoes and solid AFO’s)
- There is excessive knee flexion and a toe initial contact.

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**Test!**

- What would you predict would be the joint power for this patient?
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How do orthoses work?

- Joint kinematic shows no angular velocity.
- There can be a joint moment with no angular velocity.
- Angular velocity is needed for joint power to be possible.

How do orthoses work?

- Biomechanical basis for orthosis function

How do orthoses work?

- During gait orthoses RESTRICT atypical range of motion that may be present due to muscle weakness, joint laxity and/or abnormal loads
- In the case of weak ankle plantar flexors, the orthosis provides a force to create a plantar flexor moment

Impact of a solid ankle-foot orthosis...

Mechanical Basis Behind AFO’s

- AFO’s constrain excessive ankle dorsiflexion in stance when plantar flexors are weak
- Therefore, weight bearing on the distal aspect of the foot is possible

Impact of a knee-ankle-foot orthosis...

- Normal
- Knee adductor moment “valgus thrust”
- KAFO (supports knee adductor moment)
Orthosis Evaluation Using Motion Analysis – Part 1

Orthoses impact adjacent joints…

Typical knee  Crouch  Typical knee

Reducing excessive ankle dorsiflexion with an ankle-foot orthosis will reduce associated excessive knee flexion.

Possible Issues to Consider

• Must have sufficient range of motion to tolerate the orthosis
• Bony deformity may make brace fitting and comfort a challenge
• If there is too much restriction in movement you may limit orthosis benefits

How can we test these “hypotheses” about orthosis function?

How can we evaluate orthosis function during gait?

COMPREHENSIVE MOTION ANALYSIS

End Part 1 – Q and A