Gait Analysis Data Interpretation: Understanding Kinematic Relationships Within and Across Planes of Motion in Persons with Physical Disabilities

Sylvia Õunpuu, MSc and Kristan Pierz, MD
Center for Motion Analysis
Division of Orthopaedics
Connecticut Children’s Medical Center
Farmington, Connecticut

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Speaker Names: Sylvia Õunpuu, MSc and Kristan Pierz, MD

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We have no financial relationships to disclose.

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We will not discuss off-label use and/or investigational use in my presentation

Purpose

• To demonstrate the role of motion analysis in gaining an understanding of the relationship of joint and segment kinematics within and across planes of motion for a variety of gait pathologies
Outline

• Angle and segment definitions
• Definition of within and across plane interactions
• Case examples of within and across plane interactions
• Examples are of patients with CP unless otherwise noted

Objectives:

• Understand the importance of knowing angle definitions
• Define joint kinematic interactions within and across planes
• Develop skills to separate primary deformities vs. compensations in gait pathology

Angle definition

• The specific body segments that make up the angle
• With consideration for the orientation of the “viewer” when looking at the angle
Joint Angle Definitions

- Kinematics for the trunk, pelvis, hip, knee, and ankle/foot progression
- Coronal, sagittal, transverse planes
- Stance and swing phases of gait
Trunk Coronal Plane

- Angle Definition
  - the lateral (side to side) inclination of the long axis of the torso relative to the lab coordinate system
  - as viewed from the front and perpendicular to the plane formed by the long axis of the torso and the bi-clavicular line

Trunk Sagittal Plane

- Angle Definition
  - the forward inclination of the long axis of the torso relative to the lab coordinate system
  - as viewed by an observer looking along a line connecting the clavicles

Trunk Transverse Plane

- Angle Definition
  - the motion of the bi-clavicular line relative to the lab coordinate system
  - as seen by an observer looking down the long axis of the torso looking from above
Trunk

<table>
<thead>
<tr>
<th>Plane</th>
<th>Range of Motion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coronal</td>
<td>1 degree</td>
</tr>
<tr>
<td>Sagittal</td>
<td>3 degrees</td>
</tr>
<tr>
<td>Transverse</td>
<td>5 degrees</td>
</tr>
</tbody>
</table>

Upper Body Obliquity
- 30° up
- 10°
- 10° down
- 30° down

% Gait Cycle

25% 50% 75% 100%

Pelvis Coronal Plane

• Angle Definition
  - Angle of inclination of the right and left anterior superior iliac spine (ASIS) in relation to the horizontal
  - As viewed from the front of and in the pelvic plane

Pelvis Sagittal Plane

• Angle Definition
  - Inclination (typically anterior) of the pelvic plane with respect to the horizontal
  - As viewed by an observer looking along a line connecting the ASIS's
Pelvis Transverse Plane

- Angle Definition
  - motion of the ASIS to ASIS line relative to the lab coordinate system (direction of progression)
  - as viewed by an observer whose site line is perpendicular to the pelvic plane

Pelvis

Coronal (range of motion 8 degrees)

Sagittal (range of motion 4 degrees)

Transverse (range of motion 8 degrees)

Hip Coronal Plane

- Angle Definition
  - relative angle between long axis of the thigh and a perpendicular to the pelvic plane
  - as viewed from the front of and in the pelvic plane
Hip Coronal Plane Kinematic

- **Stance**
  - LR = adduction
  - MST/TST/PS = abduction
- **Swing**
  - ISW = abduction
  - MSW/TSW = adduction
- ROM = 13°

Hip Sagittal Plane

- **Angle Definition**
  - relative angle between the long axis of the thigh and a perpendicular to the pelvic plane
  - as viewed by an observer looking along a line connecting the ASIS's

Hip Sagittal Plane Kinematic

- **Stance**
  - LR/MST/TST = extension
  - PS = flexion
- **Swing**
  - ISW/MSW = flexion
  - TSW = minimal extension
- ROM = 43°


**Hip Transverse Plane**

- **Angle Definition**
  - motion of the thigh (as defined by the knee flexion extension axis) relative to the ASIS - ASIS line
  - as viewed by an observer above the pelvic plane

**Hip Transverse Plane Kinematic**

- **Stance**
  - LR = internally rotates
  - MST/TST = internally rotated
  - PS = externally rotates

- **Swing**
  - ISW = internally rotates
  - MSW/TSW = externally rotates

- **ROM** = $8^\circ$

**Knee Coronal Plane**

- **Angle Definition**
  - relative angle between long axis of the shank and the long axis of the thigh
  - as viewed from the front of and in the thigh plane
Knee Coronal Plane Kinematic

- Motion
  - negligible
- Position
  - neutral

Knee Sagittal Plane

- Angle Definition
  - relative angle between the long axis of the thigh and shank segments
  - as viewed by an observer looking along the knee flexion/extension axis

Knee Sagittal Plane Kinematic

- Stance
  - LR = flexion
  - MST/TST = extension
  - PS = flexion
- Swing
  - ISW = flexion
  - MSW = extension
  - TSW = extension
- ROM = 60°
Knee Transverse Plane

- **Angle Definition**
  - motion of the shank (as defined by the ankle dorsiflexion/planter flexion axis) relative to the knee flexion/extension axis line
  - as viewed by an observer above the thigh plane

Knee Transverse Plane Kinematic

- **Stance**
  - LR/MST/TST = progressive internal rotation
- **Swing**
  - ISW/MSW/TSW = progressive external rotation
- **ROM = 11(5)**°

Ankle Sagittal Plane

- **Angle Definition**
  - the relative angle between a 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 Kinematic

- Stance
  - LR = plantar flexion
  - MST/TST = dorsiflexion
  - PS = plantar flexion
- Swing
  - ISW = continued plantar flexion then dorsiflexion
  - MSW = dorsiflexion to neutral
  - TSW = minimal plantar flexion
- ROM = 30°

Foot Progression

- Angle Definition
  - Angle between the long axis of the foot (ankle center along to space between 2nd and 3rd metatarsals) and the direction of progression

Foot Progression Kinematics

- Stance
  - LR/MST/TST = progressive external rotation
  - PS = internally rotates
- Swing
  - ISW/MSW = externally rotates
  - TSW = internally rotates
- ROM = 6°
Definition:

Interactions within plane:
- Evaluation of the relationships between motion from one joint or segment to another
  - Differentiate between primary and secondary gait deviations
  - Determine possible causes of gait abnormalities

Coronal        Sagittal      Transverse
Right = solid, Left = dashed

Definition:

Sequence of data interpretation:
1. Individual joint kinematic – primary problem
2. Joints and segments within a single plane of motion that are proximal or distal

Coronal        Sagittal      Transverse
Right = solid, Left = dashed

Definition:

Interactions across planes:
- Evaluation of the relationships between motion from one plane to another
  - Differentiate between primary and secondary gait deviations
  - Determine possible causes of gait abnormalities

Coronal        Sagittal      Transverse
Right = solid, Left = dashed
Sequence of data interpretation:
1. Individual joint
2. Joints and segments within a single plane of motion
3. Joints and segments across multiple planes of motion

How does one “discover” interactions within and across planes?
• Pre versus post surgical data comparisons
• Barefoot versus orthosis data comparisons
• Lift versus no lift data comparisons
• Etc…
• Any SYSTEMATIC DATA REVIEW of problems and possible causes

Case Examples
• Interactions within planes
Coronal Plane

- Joint and segment angles
  - Up vs. down
  - Elevation vs. depression
  - Abduction vs. adduction
  - Varus vs. valgus

Increased Coronal Plane ROM

- Primary impairment – hip abductor weakness
- Associated gait issue – increased hip adduction in loading response
- Secondary deviation – increased coronal plane range of motion of the pelvis
Myelomenigocele - Lateral Trunk Lean

• Primary impairment – hip abductor weakness
• Associated gait issue – increased hip abduction and pelvic drop in stance
• Mechanism – increased lateral trunk lean in stance

Myelo - Lateral Trunk Lean

• Primary impairment – hip abductor weakness
• Associated gait issue – increased hip abduction and pelvic drop in stance
• Mechanism – increased lateral trunk lean in stance

DMD – Lateral Trunk Lean

• Primary impairment – hip abductor weakness
• Associated gait issue – increased hip abduction and pelvic drop in stance
• Mechanism – increased lateral trunk lean in stance
Knee Valgus Thrust

• Primary impairment – none at the coronal knee
• Associated gait issue – “visual” valgus thrust
• Interaction across plane…in a few minutes

Pelvic Hiking in Swing

• Visual assessment = “circumduction”
• Kinematic shows hip = neutral
Pelvic Drop in Swing

- Visual assessment of hip angle = "typical"
- Kinematic = abduction to keep thigh vertical

Knee Varus

- Impairment – fixed knee varus deformity
- Associated gait issue – increased knee varus
- Secondary deviation – hip abduction

Knee Varus

Left side – multiple gait cycles
Sagittal Plane

- Joint and segment angles
  - Forward vs. backward
  - Anterior vs. posterior
  - Flexion vs. extension
  - Dorsiflexion vs. plantar flexion

Increased Knee Flexion

- Impairment – issues related to crouch gait
  - tight/spastic hamstrings
  - hip extensor and ankle plantar flexor weakness
  - knee flexion contracture
- Associated gait issue – increased knee flexion & ankle dorsiflexion
- Secondary deviation - increased hip flexion

Increased Knee Flexion

- Increased Knee Flexion
  - Right side – multiple gait cycles
Increasing Anterior Pelvic Tilt

- Impairment – reduced dissociation between pelvis and femur
- Associated gait issue – decreased hip sagittal plane ROM (solid)
- Secondary deviations – increased ipsilateral anterior pelvic tilt and overall pelvic range of motion (solid) and increased contralateral hip range of motion (dashed)

Increased Plantar Flexion-Knee Extension Couple

Left side
Plantar Flex/Knee Ext Couple

- Impairment – increased plantar flexion knee extension couple
- Associated gait issue – increased equinus and knee extension in mid stance
- Secondary deviation – increased anterior pelvic tilt

CMT - Equinus in Swing

- Impairment – anterior tibialis weakness
- Associated gait issue – increased equinus in swing
- Compensation – increased hip flexion in swing
Equinus in Swing (Drop foot)

- Right side

Equinus in Swing

- Impairment – anterior tibialis weakness and plantar flexor tightness
- Associated gait problem – increased equinus in swing (solid)
- Compensation - increased hip flexion in swing (solid)

Equinus in Stance

- Impairment – and plantar flexor tightness
- Associated gait problem – increased equinus in stance (solid)
- Secondary deviations - ipsilateral increased anterior pelvic tilt in stance (solid), increased contralateral pelvic anterior tilt and increased hip flexion in swing (dashed)
DMD - Forward Trunk Lean

• Impairment – knee extensor weakness
• Associated gait impairment – no knee flexion in loading or stance
• Compensation – increased forward trunk lean in stance
• Knee extensor moment (internal) minimal

Transverse Plane

• Rotations
  – Internal vs. external
  – Protraction vs. retraction
  – Inversion vs. eversion
Internal Hip Rotation

Right side

- Primary impairment – femoral anteversion
- Associated gait issue – increased internal hip rotation
- Secondary deviation – internal foot progression

Pelvic Rotation Compensation

Right side
Pelvic Rotation Compensation

- Primary impairment – increased femoral anteversion
- Associated gait deviation – increased internal hip rotation (dashed)
- Pelvic compensation – increased ipsilateral external pelvic rotation (dashed)
- Secondary deviation – increased contralateral internal pelvic rotation (solid)

Transverse Plane Multiple Level Deformity

Left Side

Multilevel Transverse Plane

- Primary Impairments – increased femoral anteversion and increased external tibial torsion forefoot abduction
- Associated gait deviation – internal hip rotation
- Foot progression masks tibial torsion and foot problems

Left Side – multiple gait cycles
Case Examples

- Interactions across planes

Increased Pelvic Transverse Plane Motion

- Secondary to Reduced Knee Extension at Initial Contact
Increased Hip Abduction in Swing

- Secondary to Reduced Sagittal Plane Knee Flexion in Swing and Equinus in Swing

Increased Hip Abduction in Swing

- Secondary to Reduced Sagittal Plane Knee Flexion in Swing and Pelvic Drop in Swing

Increased Coronal Plane Hip Abduction Initial Contact

- Secondary to increased transverse plane internal pelvic rotation
Increased Coronal Plane Hip Adduction Loading Response

• Secondary to Increased Transverse Plane Pelvic Rotation

Increased Asymmetric Coronal Plane Hip Motion

• Secondary to Transverse Plane Pelvic Asymmetry

Hip coronal plane position?
Increased Hip Adduction in Stance

- Secondary to Knee Flexion & Internal Hip Rotation

Increased Pelvic Obliquity

- Secondary to a Functional Leg Length Difference

Pelvic External Rotation in Stance

- Secondary to an Excessive Plantar Flexion Knee Extension Couple (barefoot)
**Pelvic External Rotation in Stance (reduced)**

- Reduced excessive plantar flexion knee extension couple during AFO walk

**HSP – Increased Hip Abduction Swing**

- Increased internal pelvic rotation right (solid)

**HSP – Increased Pelvic Transverse Range**

- Reduced knee extension initial contact
Knee Valgus Thrust in Loading?

Apparent Knee Valgus Thrust
- Secondary to increasing
  - internal pelvic rotation
  - internal hip rotation
  - knee flexion

Neutral Knee Moment

Coronal Plane Knee Moment
Knee Varus Moment (valgus thrust)

A closer look…

Summary:
Interactions within a plane:
• Evaluation of the relationships between motion from one joint or segment to another
  – Differentiate between primary deviations and compensations
  – Determine possible causes of gait abnormalities
• Sequence of data interpretation:
  – Individual joint
  – Joints and segments above or below within a single plane of motion
Summary:

Interactions across planes:
- Evaluation of the relationships between motion from one plane to another
  - Differentiate between primary deviations and compensations
  - Determine possible causes of gait abnormalities
- Sequence of data interpretation:
  - Individual joint
  - Joints and segments within a single plane of motion
  - Joints and segments across multiple planes of motion

Thank You