AACPDM Pre-Conference Workshop

**SEGMENTAL FOOT AND ANKLE MOTION ANALYSIS**

Speakers: Gerald Harris, PhD, PE  
E-mail: gerald.harris@marquette.edu

Learning Objective: Understand how recent research and improved technology is advancing our ability to accurately assess segmental motion of the foot and ankle.

This segmental lower extremity section of the workshop will examine the clinical need and methods for segmental lower extremity (SLE) motion analysis in children and adults for pre-treatment assessment, post-treatment follow-up and longer term care. Fundamental LE modeling concepts will be presented for assessment of hip, knee, ankle and segmental foot kinematics. Examples will be presented for pes planovalgus and equinovarus.

To develop and apply **lower extremity models**, information acquired by marker sensing systems (typically optical/video) is used in conjunction with a biomechanical model to determine joint and segment kinematics (motion). A virtually limitless number of biomechanical models can be used to calculate limb orientation in space, with numerous modeling approaches reported in current literature [8-10]. Anthropometric models use positions of body-mounted markers to calculate the locations of virtual joint centers based on previously established regression equations. Cluster models rely on groups of rigidly fixed markers mounted on body segments and require technical-anatomical calibration to reference anatomical landmarks and segment axes to associated marker clusters. OJC (optimized joint center) models can be based on a variety of marker placement schemes. The OJC models rely on calibration trials for an optimized estimate of joint center locus. Collectively these modeling approaches support the development of customized models specifically tailored to the research study and/or clinical population of interest.

**Pes planovalgus** (flatfoot) is a condition characterized by a flattening of the medial longitudinal arch of the foot, along with hindfoot valgus. Physical observations of flatfoot include low arch structure, rear foot eversion, medial talar head prominence, altered gait, and calluses [1]. Positive clinical signs for planovalgus include the "too many toes sign" due to forefoot abduction and positive single limb "heel rise test" [1], [2]. Clinical gait observation is often used to assess the shape of the footprint, foot progression angle, calcaneal eversion, heel-to-toe contact, position of the knee, and the presence of a limp [1], [3]. Quantitative analysis of pes planovalgus beyond the assumption of a single rigid foot requires the use of segmental biomechanical models.
SEGMENTAL FOOT AND ANKLE MOTION ANALYSIS (CONTD.)

Equinus and varus, components of equinovarus, are two of the most common foot and ankle deformities in children with hemiplegic cerebral palsy [4]. Static or dynamic soft tissue imbalance of the ankle plantarflexors and invertors result in segmental deformities including hindfoot equinus and inversion, midfoot cavus, as well as, forefoot supination and adduction. These deformities are ultimately associated with deviations at more proximal segments, increased mechanical work, and increased energy expenditure during locomotion in children with cerebral palsy [5-7]. Quantitative gait analysis including multi-segmental foot and ankle kinematics can effectively characterize the equinovarus deformity during ambulation.

References
AACPDM Pre-Conference Workshop

Foot and Ankle Fluoroscopy

Speakers: Gerald Harris, Ph.D., P.E.
E-mail: gerald.harris@marquette.edu

Learning Objective: Understand how fluoroscopic imaging can be used to analyze bony hindfoot motion (kinematics) during gait. Illustrate opportunities for application of foot and ankle fluoroscopy for therapeutic, clinical and sports applications.

Overview of Fluoroscopy Imaging

- Image formation
- Systems components
- Clinical use

Ionizing Radiation

- Ionizing radiation
- Radiation dose & risk

Fluoroscopy in Foot and Ankle Modeling

- Errors associated with external markers
- Subcutaneous joints are difficult to model
- Alternative methods are invasive

System Hardware

- Fluoroscopy unit / Gantry
- Walkway
- Force plate
- Camera
- Imaging
- Image correction
- Image magnification
AACPDM Pre-Conference Workshop

Foot and Ankle Fluoroscopy (Contd.)

- Global referencing
- 2D Fluoroscopic hindfoot model
- Kinematics and Kinetics

Biplane Fluoroscopy in Foot Modeling
- Set-up
- Walkway with force plate
- X-ray sources and image intensifiers
- Calibration
- Image distortion correction
- Volume calibration
- Bone Models
- CT and MRI of foot
- Segmentation of Bones
- Model-Based tracking
- Input: Bone models and image sequences in virtual space
- Output: Six degrees of freedom of bones
- Kinematics and Kinetics of talocrural and subtalar joints
- Inverse Dynamics and ground reaction forces

Application Examples
- Clinical
- Therapeutic
- Sports