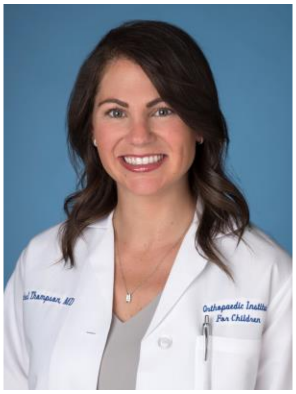
Los Angeles Pediatric Society E-Newsletter
Volume 6 No. 1 May 2019

SPECIALISTS' CORNER



Basic Principles in Modern Gait Analysis

Rachel M. Thompson, MD
Pediatric Orthopaedic Surgeon, Assistant-Professor-in-Residence, David Geffen School of Medicine at UCLA, Associate Director for the Center for Cerebral Palsy at UCLA/OIC

Instrumented 3-dimensional motion analysis is an invaluable tool utilized by orthopaedic surgeons, physical therapists, orthotists and researchers to gain insight into normal gait patterns and gait disturbances. Gait analysis is utilized primarily in academic centers as it is costly, time-consuming and requires expertise in gait analysis and engineering. Regardless of these limitations, it has wide applicability in joint arthroplasty, prosthetics, ligamentous reconstruction (i.e. ACL reconstruction), congenital deformity and neuromuscular conditions. The most common application of gait analysis in pediatric populations is in pre-operative and post-operative assessment of gait disturbances associated with cerebral palsy. Gait analysis accurately quantifies components contributing to gait abnormalities for operative planning. It further allows for accurate, objective assessment of surgical success post-operatively.

The gold standard for gait analysis is infrared 3-dimensional motion capture technology. Infrared motion capture technology, along with electromyography (EMG) and force plate analysis, offers accurate analysis of human movement (Figure 1). In addition to the

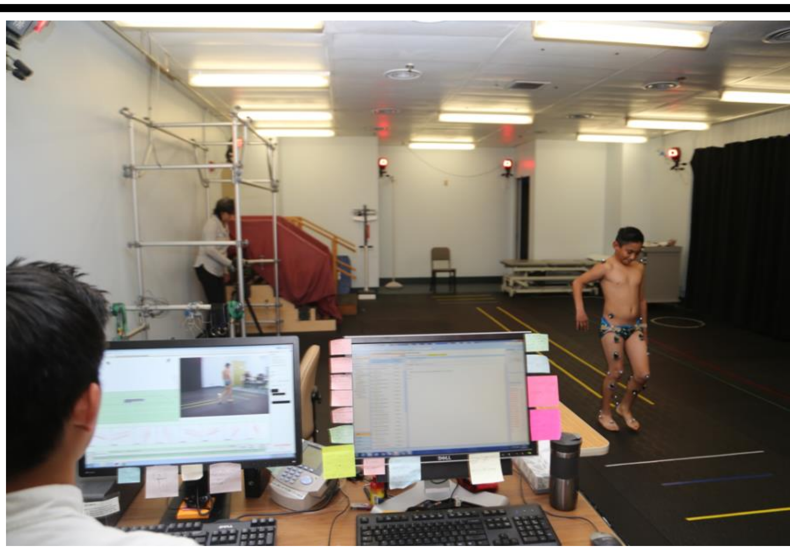


Figure 1. Modern motion analysis laboratory. Patients walk over force plates built into the ground while wearing reflective markers placed at discreet locations, which are recognized by the infrared cameras (8 total), which allows for objective evaluation of joint kinematics and kinetics. Mobile surface-EMG markers have been placed on this patient, which record muscle activity during the gait cycle.

instrumented analysis, each gait evaluation includes a physical exam by a clinician and a qualitative videotape of the patient walking naturally.

The physical exam is typically performed by a physical therapist with training in gait analysis, which includes an evaluation of passive joint range of motion utilizing a goniometer, manual muscle strength testing, spasticity as measured by modified Ashworth scale[1] and selective motor control as measured by the Selective Control Assessment of the Lower Extremity[2]. The physical exam provides baseline information that may inform surgical decision making. For example, a child with fixed knee flexion contractures as measured by passive range of motion requires a different surgical plan than a child without fixed contractures regardless of the fact that both children may be walking with flexed knees.

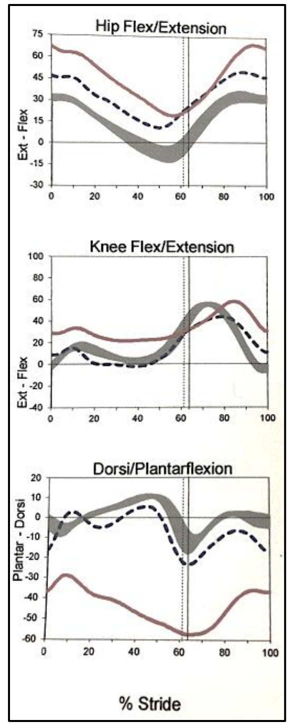
The qualitative video is shot with the patient walking barefoot from 2 vantage points (side view and front/back). In certain patients, a second video is shot with the patient wearing their foot wear and orthotics. The video exam allows for a controlled subjective evaluation of overall fluidity of movement and gross abnormalities that may be played repeatedly and in slow-motion to allow for more detailed observation.

After these two exams are completed, reflective markers are placed on the surface of the patient's skin, aligned with bony landmarks and joints. The patient walks along a straight pathway over force plates, and the locations of the markers are monitored by the infrared motion capture system (6-8 cameras placed around the walk-way). Each camera emits infrared light (not seen by the patient), which is reflected by the markers back to the camera. A centralized computer system reads these signals and can determine the location of the markers in space. Marker position data allows for angular orientation of each body segment throughout gait, termed *kinematics*. Force plates embedded in the pathway measure the reaction between the foot and the ground, which allows for the calculation of the load across each joint in the lower extremity, termed *kinetics.* Electromyography electrodes on the surface of the skin or inserted as fine wires into muscles allow for muscle activation/deactivation to be monitored in real-time during ambulation. The information obtained is then synthesized into graphs comparing the examined patient compared to age-matched normative data.

Taken together with the clinical exam and observational video, kinetics, kinematics and EMG data are analyzed by a team of engineers, physical therapists and orthopaedic surgeons to determine the primary and secondary pathology causing gait disturbances to guide surgical decision-making.

For example, the graphical output shown in Figure 2 is the sagittal plane (side-view) of a child with hemiplegic cerebral palsy (right-side affected). Watching the child walk, he keeps his right hip and knee flexed and ankle plantarflexed throughout all of stance-phase (portion of gait with the foot on the ground). This clinical picture may suggest that this child would benefit from ankle, knee *and* hip surgery. However, his kinematics suggest the greatest pathology is at his ankle, and his clinical exam revealed that he had a fixed equinus contracture (lack of passive dorsiflexion) of the ankle with full range of motion of the knee and hip. As such, the ankle plantarflexion is the *primary* pathology, while the flexed knee and hip are secondary changes resulting from the ankle contracture. As such, the decision was made to address the ankle contracture with an achilles lengthening only, avoiding unnecessary surgery at the knee and/or hip.

Figure 2. Example of sagittal-plane (side view) kinematics for a child with hemiplegic (right) cerebral palsy that toe-walks on the right side. Gray band is age-matched norms, red is right and hashed is left. The first 60% of the gait cycle measures the limb in "stance," and the terminal 40% measures the limb in "swing."



In this way, gait analysis is a valuable tool that synthesizes thousands of objective data points into analyzable outputs. Clinicians trained in gait analysis may utilize this data to inform not only orthopaedic surgery but the efficacy of orthotics and other therapeutic interventions. Given the reliability and objectivity of this tool, it is advisable to utilize gait analysis for pre-operative planning where available, especially in children with complex neuromuscular disease, like cerebral palsy. For more information, please visit uclaccp.org.

1. Bohannon RW, Smith MB. Interrater reliability of a modified Ashworth scale of muscle spasticity. *Phys Ther.* 1987;67(2):206-207.
2. Fowler EG, Staudt LA, Greenberg MB, Oppenheim WL. Selective Control Assessment of the Lower Extremity (SCALE): development, validation, and interrater reliability of a clinical tool for patients with cerebral palsy. *Dev Med Child Neurol.* 2009;51(8):607-614.