Appendix 6

Gait analysis

The precise elements of gait analysis vary slightly between institutions. Gait analysis at Gillette Children's includes the following elements, described in more detail below:

- Medical history
- X-rays
- Parent-reported (or individual-reported) functional questionnaires
- Two-dimensional video
- A standardized physical examination
- 3D computerized motion analysis
    - Kinematics: 3D measurement of motion (movement)
    - Kinetics: 3D measurement of forces and mechanisms that cause motion
- Electromyography (EMG): Measurement of the activity of muscles
- Pedobarography: Measurement of the pressure distribution under the feet
- Energy expenditure: Measurement of the energy used during walking

Preparing for a gait analysis: What to expect

A typical gait analysis takes about two and a half to three hours. However, it is broken down into the elements listed above, none of which takes very long. The longest portion is usually the physical examination.

For children, two and a half to three hours is a long time to remain cooperative, It's important to make sure that they are is well rested and well fed before the appointment It's helpful to have a snack or drink on hand in case they need it to keep up their energy.

The gait lab usually specifies the type of clothing the child should wear to the appointment; for example, loose-fitting shorts and a tank top for girls and just the shorts for boys. Any orthoses and walking aids (e.g., crutches, walkers, or canes) used should also be brought.

The gait lab has a special walkway about 20 meters long, with special plates in the floor over which the child walks. The plates measure the forces produced as they walk. There are also cameras around the room for the two-dimensional video recording.

The elements of gait analysis explained

The following details the different elements of gait analysis at Gillette Children's and will be a useful guide to gait analysis at most centers. It may be helpful to refer to section 2.5 on typical walking as you read this.

Medical history

Medical history includes information on:

- Birth history

- Developmental milestones
- Any medical problems
- Surgical history
- Current physical therapy program
- Current medications
- Parent (or individual) report on functional walking at home, school, and in the community and other functional skills (e.g., climbing stairs, running, jumping)
- Any complaints of pain
- Any behavioral or learning issues
- Reason for referral to gait lab, including current surgical or treatment considerations
- Goals for treatment

Parent-reported (or individual-reported functional questionnaires

The following questionnaires are completed:

- To measure function in the community
    - Gillette Functional Assessment Questionnaire (FAQ), Walking Ability and Higher-Level Functional Skills
    - Pediatric Outcomes Data Collection Instrument (PODCI)
    - Gait Outcomes Assessment List Questionnaire (GOAL)
- To measure goals:
    - Gait Outcomes Assessment List Questionnaire (GOAL).

(Details of these measurement tools are included in Appendix 1.)

Two-dimensional video

This visual record is useful for understanding an individual's gait problems and for comparing gait before and after treatment. The information obtained by observing them walk complements the information obtained from the 3D computerized motion analysis equipment. It is useful to see how the individual walks without any of the marker equipment used in 3D computerized motion analysis. Any problems with posture and balance in standing and walking are also noted. See Figure A6.1.

Figure A6.1 Two-dimensional video.

Standardized physical examination

The following are typically measured in the physical examination:

- Muscle strength
- Selective motor control
- Muscle tone
- Range of motion and contractures
- Bone deformity
- Fixed and mobile foot deformities
- Leg length
- Extensor lag (the difference between the active and passive knee extension)
- Ligament laxity (loose ligaments)

Gait laboratories usually have very standard protocols for completing each.

3D dimensional computerized motion analysis

3D computerized motion analysis provides a very detailed analysis of walking. The equipment for this is the same technology as that used for animation in the film and video game industries. The clinician, usually a physical therapist, applies small markers to the individual' body at specific points. See Figure A6.2.

Figure A6.2 Applying markers for 3D computerized motion analysis.

As a person walks, many changes occur at different joints in the body and in different planes. In addition to the many changes that occur in normal walking, a person with CP has a combination of primary, secondary, and tertiary abnormalities that interfere with their walking. The speed of these changes as they walk is far greater than the speed at which the observer can process the changes. The cameras capture the markers at high speed (120 frames per second) and provide far more information than can be gleaned even with a very experienced eye or from watching slow-motion videotape (30 frames per second). The information from the cameras is synchronized with information from the force plates and muscle activity so that all the data is collected simultaneously.

The 3D computerized motion analysis output allows the staff to compare the person's walking pattern with data collected from normal walking. Once the differences are identified a list of deviations drawn up.

The following describes how Gillette displays gait data; other gait laboratories may produce the data slightly differently.

a) Kinematics

Kinematics is the quantitative 3D measurement of motion (movement). Kinematics show what is happening at the trunk, pelvis, hip, knee, and ankle on both sides of the body and in all three planes of motion. The kinematic graphs show the position and pattern of each body segment at each point in the gait cycle. See Figure A6.3.

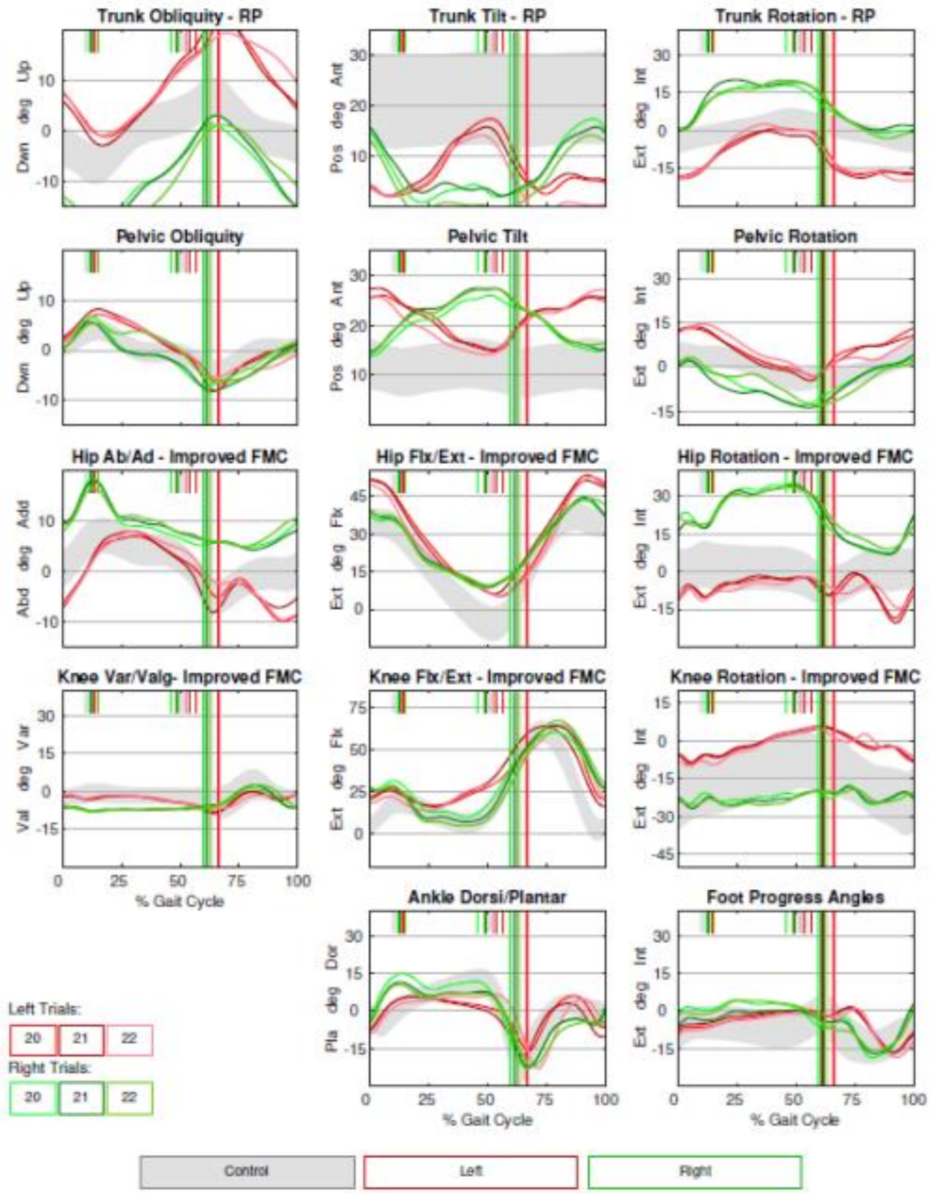

Figure A6.3 Kinematic graphs.

The horizontal axis of all graphs represents one full gait cycle. The shaded areas show the gait patterns of typically developing children. The area left of the vertical line represents when the foot is on the ground (stance phase, approximately 60 percent of the gait cycle); the area to the right represents when the foot is in the air (swing phase). The right lower limb is labeled green, and the left is labeled red. The graphs for both legs are synchronized.

The five rows of individual graphs represent the trunk, pelvis, hip, knee, and ankle, respectively. The three columns represent the three planes of motion. From left to right, they are:

- From the back or front: the coronal plane
- From the side: the sagittal plane

- From the top or bottom: the transverse plane

When looking at kinematics, the points to note are how well the person's graphs (green and red) match normal gait (the shaded area). Does the shape (pattern and position) of the graph for each limb match normal gait? Is the timing of events within the gait cycle (e.g., stance and swing time) normal?

b) Kinetics

Kinetics help to explain the movement seen in the kinematic graphs. Kinetic data is obtained from the special plate data combined with kinematics. See Figure A6.4.

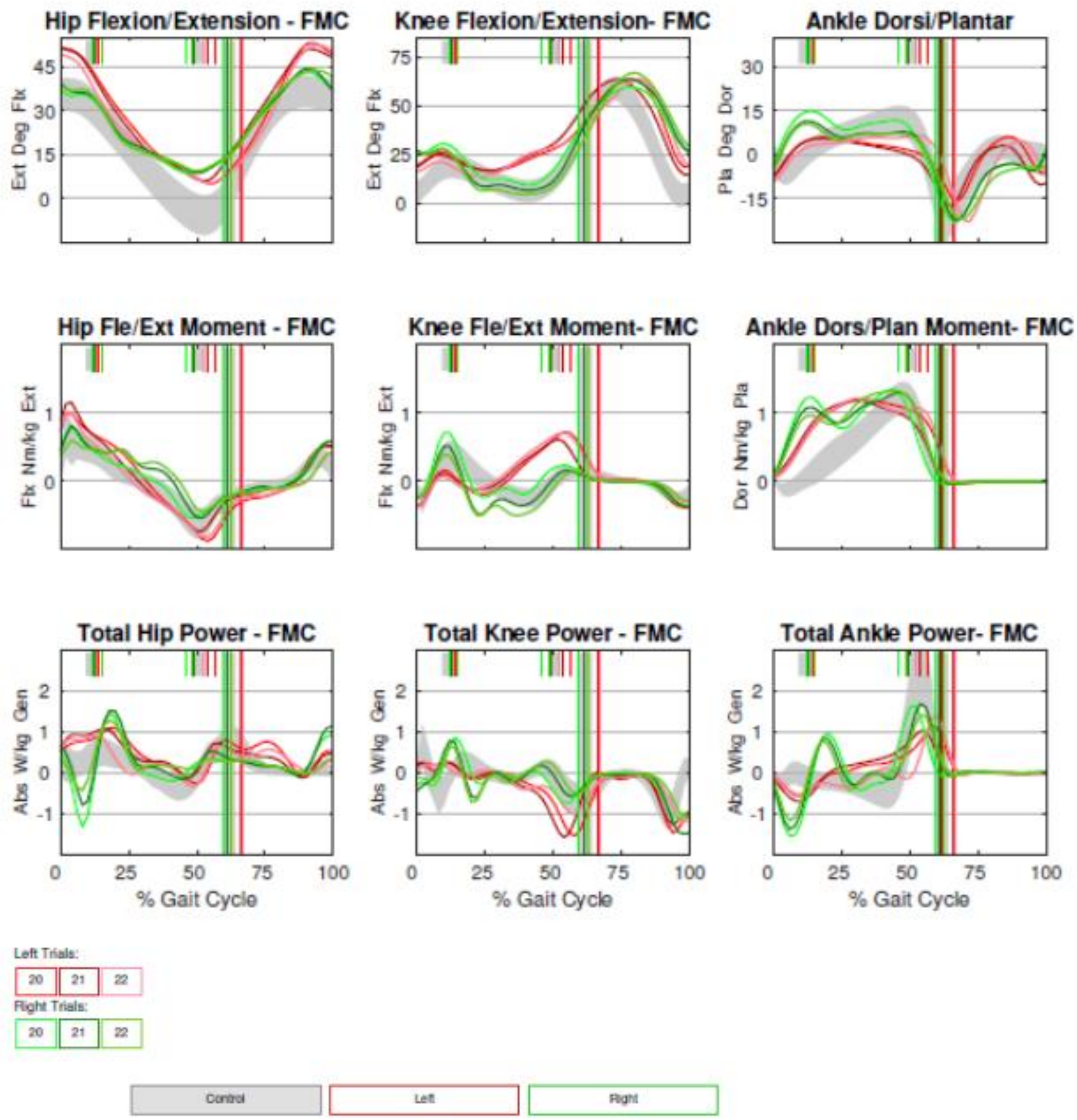

Figure A6.4 Kinetic graphs.

The kinetic graphs show:

- First row: The person's kinematic graphs at hip, knee, and ankle level (i.e., what is happening during the gait cycle). These are just included for reference.
- Second row: The moments generated at these joints during the gait cycle. Remember, a "moment" is a force (e.g., a muscle contraction) acting on a lever (the bone] about a joint, which produces movement.
- Third row: Power at these joints (a combination of how fast the joint is moving and the moment being produced) during the gait cycle.

The moment (second row) and power (third row) graphs provide information about the cause of gait abnormalities—the "why" that explains the "what" of the kinematics (first row).

Again, when looking at kinetics, the points to note are how well the person's graphs (green and red) match normal gait (the shaded area). Does the shape (pattern and position) of the graph for each limb match normal gait? Is the timing of events within the gait cycle (e.g., stance and swing time) normal?

Kinetic graphs are generated in two planes—the coronal and sagittal planes. The graphs shown are from the sagittal plane.

Electromyography

Electromyography (EMG) is the measurement of the electrical activity of the muscles. It provides information about the amount of muscle activity. There are times in the gait cycle when a muscle is supposed to be working and times when it is supposed to be silent. A typical EMG graph is displayed in Figure A6.5.

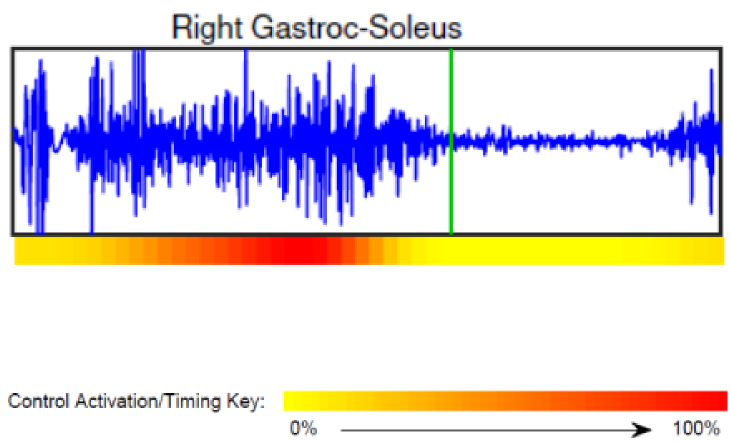

Figure A6.5 EMG graph.

The graph of the person having gait analysis is compared with normal gait, which is shown in the colored bars underneath the graph: yellow when the muscle is silent and reddest when it is most active. The blue line shows when the muscle is contracting and when it is not. In the figure, the blue line displays that this muscle is not working correctly because it comes on earlier than it should at the beginning of the gait cycle and lasts a little longer. Also, the muscle is active at the end of the gait cycle when it should be silent.

In addition to looking at activity patterns in individual muscles, activity patterns between muscles are also assessed Some groups of muscles are expected to work together, while others are expected to work opposite each other. While one of the agonist-antagonist pair (addressed in section 2.4) is working, the other is expected to be silent. (The gastrocnemius and the tibialis anterior are an example of an agonist-antagonist pair.)

Information from EMG is used to look for signs of spasticity—whether muscles are turning on and off at appropriate times. It also checks if the muscles are working all together or all on or off at the same time—signs of patterned movement that indicate poor selective motor control. The EMG graphs are studied in conjunction with the kinematic and kinetic graphs.

Pedobarography

Pedobarography is the study of pressures underneath the foot. The person walks across a special mat that senses the pattern and distribution (high or low) of pressure under the feet. It is dynamic because it captures this information while the person is walking. (This technology is used in some sports shops when selling running shoes.) See Figure A6.6.

Figure A6.6 Testing foot pressure.

Figure A6.7 shows plantar pressure graphs of a person's left and right sides. The colors indicate the magnitude of the pressure: red indicates high pressure and blue indicates low pressure. In gait analysis, any deviations from the normal pattern distribution of pressure under the feet are noted. In this example, the person bears weight only on the ball of their right foot.

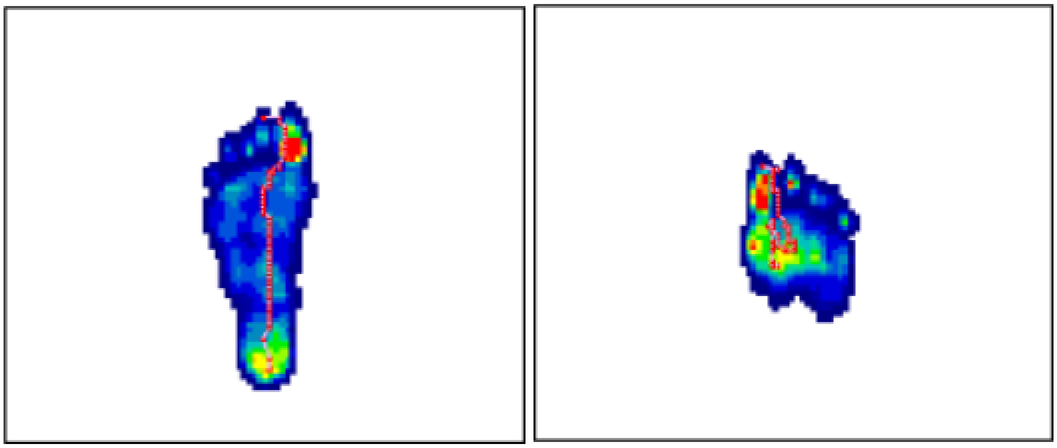

Figure A6.7 Plantar pressure graphs of left and right sides.

Energy expenditure

As a result of the deviations in gait, people with CP frequently walk in a manner that is less energy efficient than normal walking. An energy expenditure test provides an objective measure of a person's energy efficiency during walking.

The person wears a mask that covers their nose and mouth, and the equipment measures the amount of oxygen they inhale and carbon dioxide they exhale. First measured is resting energy expenditure, with the person sitting for 10 minutes. (See figure A6.8.) They then walk for six minutes to measure their movement energy expenditure.

Figure A6.8 Measuring energy expenditure.

In labs that do not have this equipment, a timed walk test may be conducted as an indirect indicator of the energy efficiency of walking.