Appendices: Spastic Diplegia

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Appendix 1

Measurement tools

Table A1.1 lists examples of some commonly used measurement tools in CP.

Table A1.1 Measurement tools used in CP

Measurement tool	Variable
DAYC (Developmental Assessment of Young Children)	Cognition, communication, social-emotional development, physical development, and adaptive behavior
Peabody Developmental Motor Scales	Gross and fine motor function
Bayley Scales of Infant and Toddler Development	Cognition, communication, social-emotional development, physical development, and adaptive behavior
Goniometer	ROM of joint
GMFM (GMFM-88 and GMFM-66)	Gross motor function
10-meter or 6-minute walking test	Walking
Gillette Functional Assessment Questionnaire (FAQ)	Functional mobility
Functional Mobility Scale (FMS)	Functional mobility
Gait Outcomes Assessment List (GOAL)	Gait priorities and functional mobility
Pediatric Outcomes Data Collection Instrument (PODCI)	Pediatric health
PEDI-CAT	Daily activities, mobility and social/cognitive function
Canadian Occupational Performance Measure (COPM)	Self-perception of performance in everyday living

Appendix 2

Managing upper limb function

With spastic diplegia, the lower limbs are much more affected than the upper limbs, which frequently only show fine motor impairment. For those with spastic diplegia who have upper limb involvement, the following addresses occupational therapy for managing upper limb function, including the use of orthoses. Some occupational therapists—certified hand therapists—also specialize in upper limb involvement.

Information is also included on adaptive equipment to support activities of daily living (ADLs) and recreational activities.

Individuals with CP GMFCS levels I to III generally do not need tone reduction or orthopedic surgery for upper limb problems.

Stretching and strengthening

As with physical therapy, occupational therapy contains elements of stretching and strengthening. These may be included to directly help with an occupational therapy activity.

Orthoses

Occupational therapists play a large role in assessing and identifying appropriate orthoses to enhance participation in ADLs. Upper extremity orthoses are used for the fingers, hands, wrists, elbows, and shoulders. They are intended to maintain ROM of the joint, to provide support, and/or to maximize positioning and function. The following upper extremity orthoses may be used in upper limb involvement and are described in Table A2.1:

- Hand finger orthosis (HFO)
- Wrist hand finger orthosis (WHFO)
- Wrist hand orthosis (WHO)
- Elbow orthosis (EO)

Table A2.1 Common upper extremity orthoses for individuals with upper limb involvement

ORTHOSIS TYPE	SUBTYPE	DESCRIPTION
Hand finger orthosis (HFO)	Static 	A static HFO is a device that fits in the palm of the hand and allows the fingers to wrap around it. This counteracts finger flexion contractures and prevents the pain and skin breakdown that can result from maintaining a prolonged fist position.
	Finger 	The finger HFO is worn on the hand and fingers. It is made either of a rigid material to help extend and stretch the fingers or a softer material to assist with grasp, release, and positioning of the hand. These orthoses can help with functions such as pressing a button or improving grasp. (Note: This HFO includes a thumb abduction component to assist with thumb positioning.)
	Thumb abduction orthosis 	A thumb abduction orthosis covers the hand and thumb. It can be made from rigid thermoplastic* or softer, flexible neoprene material. It supports the thumb joint in a functional grasp position, preventing hypermobility, and it can be useful during play activities. It also prevents the thumb from coming into the palm during fisting.
Wrist hand finger orthosis (WHFO)	Static  	A static WHFO holds the wrist, hand, and fingers in one position and does not allow movement. The rigidity of the material can vary, and it may be worn at night or at rest due to its impact on the user's functionality. It is typically used to counteract or prevent painful wrist and/or finger contractures.

Wrist hand orthosis (WHO)		A WHO covers only the wrist and hand (not the fingers). It can be made of a variety of materials including neoprene, nylon, thermoplastic,* or metal. A WHO helps to maintain wrist positioning while allowing finger flexion and thumb opposition (touching the tip of the thumb to the tip the fingers).
Elbow orthosis (EO)		An EO (elbow immobilizer) is worn around the elbow joint. There are a variety of options, from static EOs that maintain one position to counteract flexion contractures and protect the joint, to dynamic EOs that allow movement and can improve ROM. The image is of a static EO.

* Thermoplastic material becomes more pliable when heated and is therefore useful for making or adjusting orthoses. *Adapted from Ward and colleagues. Dynamic WHFO image reproduced with kind permission from Saebo Inc.*

Constraint-induced movement therapy and bimanual therapy

Using both hands reflects everyday typical hand function. Constraint-induced movement therapy (CIMT) and bimanual therapy (performed with both hands) are two therapy types that encourage the use of the affected arm or hand. Naturally, an individual with upper limb involvement tends to favor using their unaffected hand because it functions so well.

These therapies are appropriate in spastic diplegia if there is considerable upper limb involvement, but not if there is only minimal to no upper limb involvement.

CIMT and bimanual therapy can help maintain ROM, prevent learned disuse, and increase awareness of the presence and functionality of the affected arm and hand. Both interventions require a high level of parent and child education and engagement, as practicing skills at home when not in structured therapy will optimize gains of either intervention.

CIMT involves two main components used in combination: restraint of the unaffected hand and intensive structured therapy. The restraint may be a soft restraint such as a mitten (on the unaffected hand). In an older child, a cast on the unaffected arm and hand may be used to enable longer periods of treatment. The child then participates in games and activities that require use of their affected hand.

Bimanual therapy consists of games and activities designed to improve the child’s ability to use both arms or hands together (without any restraint placed on the unaffected hand). It involves a high level of repetition. This therapy helps translate to the child using their affected upper limb in everyday tasks such as carrying a lunch tray at school.

CIMT and bimanual therapy tap into the brain's neuroplasticity. There is strong evidence supporting both (green light).[1] It is recommended that CIMT and/or bimanual therapy begin as soon as upper limb involvement is suspected.[2] Each of these therapies has different functions so one should not be chosen over the other; it is good to do both in sequence.

Robot-assisted therapy

Robot-assisted therapy involves using a robotic device to support the arm in movement and task completion (see Figure A2.1). Research supports its use.[3]

Figure A2.1 Robot-assisted therapy.

Table A2.2 shows appropriate ages for different upper limb therapies, although each of these therapies remains relevant throughout life.

Table A2.2 Appropriate ages for upper limb therapies

THERAPY	APPROPRIATE AGES
CIMT	3 months to 18 years
Bimanual therapy	Infancy through adolescence
Robot-assisted therapy	4 years plus; depends on size of child as there is a minimum size needed to engage with most devices

Activities of daily living

Occupational therapy to enhance an individual's ability to perform or assist with activities of daily living (ADLs) is goal based, and for individuals with upper limb involvement, ADLs focus on performing tasks independently such as dressing, grooming, feeding, bathing, and toileting. The therapy is informed by the individual's motor abilities, cognitive abilities, and impairments. For example, occupational therapists often screen for vision impairments and use these screening results to plan ongoing treatment and adapt activities appropriately, taking into consideration how vision impairment may impact actions such as hand use. Specific ADLs focused on during occupational therapy also change depending on age:

- Young children—focus is on activities that feel like play, encouraging the child to engage and participate.
- Middle childhood to adolescence—focus is on increased engagement in family responsibilities, organized activities, and socialization, such as completing weekly chores (e.g., setting the table, taking out trash) and participating in sports and recreational opportunities to begin building skills and capacity for independence in adulthood.
- Adolescence to young adult—focus is on building skills for living independently and managing adult tasks such as scheduling appointments or managing money.

Occupational therapists can also make recommendations for adaptive equipment for completing ADLs. The following may help:

- Adaptive shoes with Velcro, zipper closures as opposed to laces, to allow for easier fastening
- Clothing with magnetic zippers[*]/zipper pulls[†] to allow for easier dressing

There are also many "one-handed techniques" that allow for shoe tying and dressing that don't include equipment.

The following are examples of equipment that may help with food preparation and eating:

- Adaptive cutting board to help secure a food item to allow for cutting with one hand. See Figure A2.2.

[*] Uses magnets instead of traditional interlocking teeth or coils to fasten two sides of a garment together. They typically have strips of magnets embedded along the edges of the fabric, which attract each other to create a secure closure when brought together.
[†] A small, usually metallic or plastic attachment that can be put on the slider of a zipper, making it easier to open and close.

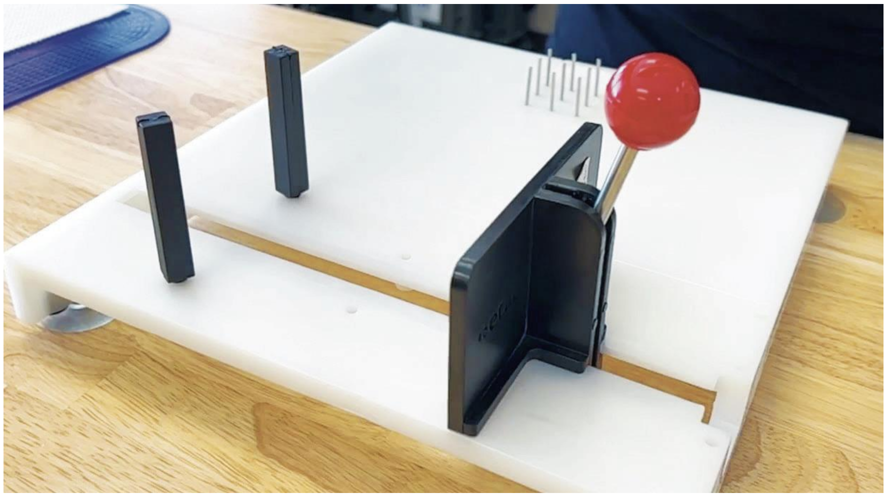

Figure A2.2 Adaptive cutting board. Reproduced with kind permission from Rehab-Store.com.

- Adaptive silverware to allow the weak hand to assist with eating. See Figure A2.3.

Figure A2.3. Adaptive silverware.

Building autonomy

An important part of occupational therapy is building autonomy—maximizing the capacity for the individual to be independent. Goals for independence are set based on functional and cognitive abilities. For individuals with upper limb involvement, these goals may center on the ability to live independently and complete necessary home management tasks such as cooking, cleaning, and grocery shopping. They may also include skills such as money management and medication management.

Adaptive recreational equipment

Examples of adaptive recreational equipment that may help individuals with upper limb involvement include:

a) Technology options
b) Adaptive art and crafts equipment
c) Reading stands
d) Adaptive equipment for games

a) Technology options

An adaptive joystick and adaptive color-coded keyboard with large keys and letters can help with computer use (see Figure A2.4).

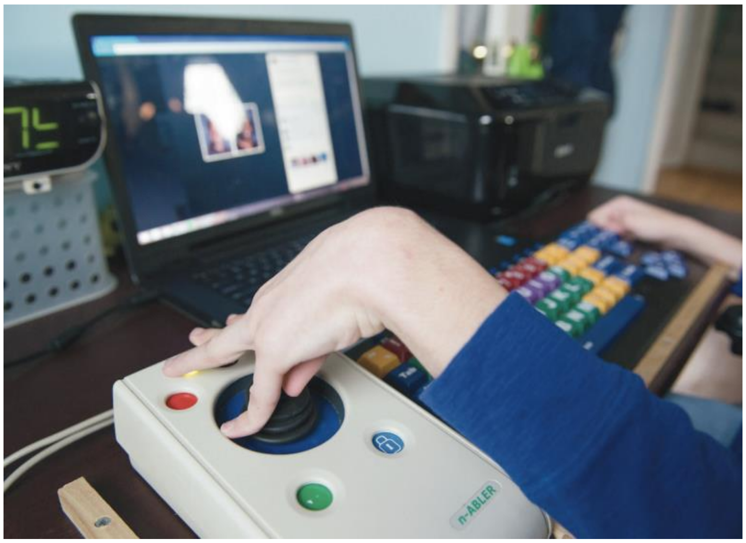

Figure A2.4 Adaptive joystick and keyboard.

b) Adaptive art and crafts equipment

Adaptive art and crafts equipment may include:

- Single-extremity scissors with a stability base
- Single-extremity scissors
- Easy-grip scissors
- Universal cuff (can be used for many purposes; here to hold a writing utensil)
- Foam grip aid to assist weak grip
- Paintbrush holder that may prevent fatigue
- Glue dots, paper clamps, easels, and egg-shaped palm crayons

See Figure A2.5.

Figure A2.5 1) Single-extremity scissors with stability base; 2) Single-extremity scissors; 3) Easy-grip scissors; 4) Universal cuff; 5) Foam grip aid.

c) Reading stands

A table-top book stand allows for page turning (see Figure A2.6).

Figure A2.6 Table-top book stand.

d) Adaptive equipment for games

Adaptive equipment for playing games may include the following:

- Card shuffler
- Card holder
- Adaptive switch for use with a regular soap bubble-maker
- Dice popper

See Figures A2.7 to A2.10.

Figure A2.7 Card shuffler.

Figure A2.8 Card holder.

Figure A2.9 Adaptive switch for use with a regular soap bubble-maker.

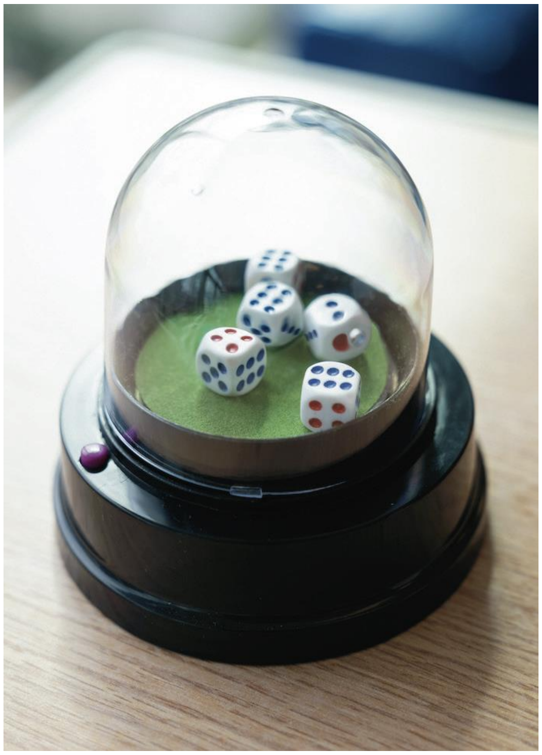

Figure A2.10 Dice popper.

References

1. Novak I, Morgan C, Fahey M, et al. (2020) State of the evidence traffic lights 2019: Systematic review of interventions for preventing and treating children with cerebral palsy. *Curr Neurol Neurosci Rep,* 20, 1-21.
2. Morgan C, Fetters L, Adde L, et al. (2021) Early intervention for children aged 0 to 2 years with or at high risk of cerebral palsy: International clinical practice guideline based on systematic reviews. *JAMA Pediatr*, 175, 846-858.
3. Gilliaux M, Renders A, Dispa D, et al. (2015) Upper limb robot-assisted therapy in cerebral palsy: A single-blind randomized controlled trial. *Neurorehabil Neural Repair*, 29, 183-92.

Appendix 3

Scoliosis management

Treatment options for scoliosis can range from nonsurgical methods, such as observation with repeat X-rays, to surgical methods, such as spinal fusion. Treatment options include the following (note that goals are shown in italics):

- Observation: Regular spine X-rays and clinical exams with a spine specialist *to monitor scoliosis curve for possible progression.*
- Bracing: A spinal brace that applies corrective forces to the spine *to slow or stop scoliosis curve progression.*
- Surgery: Surgery performed *to prevent future progression and improve the scoliosis curve (decrease the Cobb angle).* There are many types of scoliosis surgery. The most common type is spinal fusion, defined as fusing (joining together) two or more vertebrae in the spine; screws and metal rods are typically used to hold the spine in the straightened position and facilitate fusion between bones.

Table A3.1 summarizes these treatment options

Table A3.1. Treatment options for managing scoliosis

Treatment options	Indications	Goals
Observation		
Skeletally immature	Cobb angle less than 20 degrees	Monitor scoliosis curve through repeat X-ray images for possible progression
Skeletally mature	Cobb angle between 30 and 50 degrees	
Bracing		
Skeletally immature	Cobb angle between 20 and 45 degrees	Slow or stop scoliosis curve progression Prevent or delay surgery
Skeletally mature	Not an appropriate treatment once skeletally mature	
Surgery		
Skeletally immature	Cobb angle greater than or equal to 50 degrees	Stop curve progression Improve the spinal curve (decrease the Cobb angle) Achieve a balanced spine and posture
Skeletally mature	Cobb angle greater than 50 degrees	

More information on scoliosis management in CP is available in the book *Congenital, Neuromuscular, Syndromic, and Other Causes* in the **Gillette Children's Healthcare Series**.

Appendix 4

Positioning

Positioning to achieve stretch

Examples include:

- **Long sitting**: This stretches the hamstrings, as the knees are extended while the hips are flexed. For the younger child this can be done without a special seat, though a special seat that promotes the 90-degree angle of the hip and ties the knee in extension can be a great help. (See Figure A4.1.) If an AFO plus knee immobilizer are worn while the child is positioned in long sitting, stretch of both the calf and hamstring muscles can be achieved.

Figure A4.1 Long sitting.

- **Side sitting**: This gives a nice stretch to the side with the balancing hand. It also stretches the wrist if there is any upper extremity tightness. See Figure A4.2.

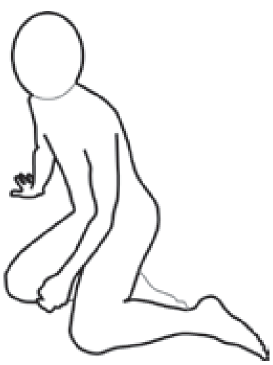

Figure A4.2 Side sitting.

- **Tailor sitting**: This stretches the hip adductors but also promotes hip external rotation. See Figure A4.3.

Figure A4.3 Tailor sitting.

- **Prone positioning**: This stretches the hip flexors. Prone propping is a position in which the child lies on their tummy with their feet out behind them and elbows on the floor. In prone lying, the elbows are straight. A triangular wedge is very handy to help promote this position. See Figure A4.4.

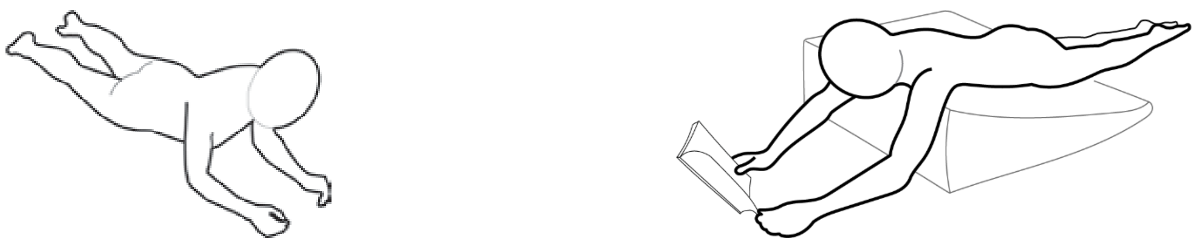

Figure A4.4 Prone propping.

- **Standing**: This stretches the hip flexors, the hamstrings (knee flexors), and the gastrocnemius and soleus muscles. This includes standing while holding on to furniture, standing with orthoses or knee immobilizers, and standing with various standing equipment. Sometimes the equipment allows children to stand on an incline, which helps stretch the gastrocnemius muscle.

Some positions for strengthening

Examples include:

- **Prone positioning** (prone propping; see explanation above): This position promotes shoulder stability and improves trunk control through core strengthening. Crawling involves movement while in a prone position.
- **Tailor sitting**: This promotes the development of trunk control (i.e., trunk strengthening and balance reactions). It also encourages more active play, and because the two hands are free, it encourages crossing the midline (using both sides of the body together).
- **Standing**: Standing strengthens trunk and leg muscles. Playing while standing is also important for developing balance reactions.
- **Side sitting**: This promotes the development of trunk control and balance reactions. It should be practiced evenly on both sides.

- **Sitting on a large roll or bolster with feet supported on the floor**: The child can play at a table in this position. The hips, knees, and ankles are at 90 degrees and both sides of the trunk are straight. This promotes the development of trunk control (i.e., strengthening the trunk muscles and balance reactions). It also encourages more active play, and because the two hands are free, it encourages crossing the midline. See Figure A4.5.

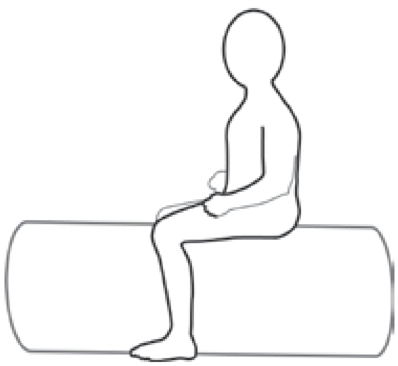

Figure A4.5 Sitting on a large roll.

- **Tall kneeling**: In this position, the child is bearing weight on their knees. The knees are flexed but the hips and trunk are extended. This position again promotes the development of trunk control and balance reactions, but because it is done in a kneeling rather than a sitting position, there is more work being done to oppose gravity. This is a good precursor to standing balance, and it is a good play position even if the child has already achieved standing. Some children also practice walking on their knees. See Figure A4.6.

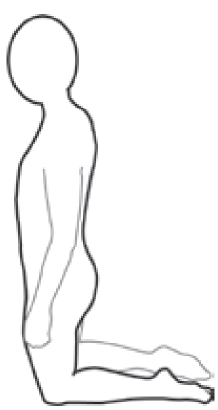

Figure A4.6 Tall kneeling.

Appendix 5

Exercise and physical activity

There's a balance to be struck between preserving joints and allowing a child to play sports and do activities they most enjoy. For example, if playing soccer with friends is a favorite activity for a child, then it's a good sport for that child. Swimming is a particularly good sport because of its low impact on the joints.

Exercise and physical activity tips for the younger child

- The typically developing toddler gets their muscle stretching and strengthening exercises through everyday movement: running, climbing, jumping, etc. Since one of the goals is to follow typical development as much as possible (to get normal forces acting on the bones), the young child with spastic CP needs to get their required amount of exercise and physical activity. Movement is essential, including moving joints through the entire ROM the child is capable of.
- For the young child, learning to play and learning *through* play are very important. Incorporating exercise and stretching into the normal day as much as possible also helps—for example, encouraging the child to use a tricycle to travel short distances.
- Playgrounds (both outdoor and indoor) are great places for all children to play, but they are especially important for the child with CP. Here the child has the opportunity to move in a variety of ways. Playgrounds are also great because they are typical family settings. Parents of children with limited mobility sometimes tend to avoid taking them to venues that require a lot of movement, which is unfortunate because a child with CP needs such opportunities to move and play even more than the typically developing child. Safety is a concern, of course, but parents should avoid being so overzealous about safety that their child misses out on opportunities for movement.
- Swimming is a great activity for the young child with CP.
- Parents may be reluctant to use adaptive equipment (such as a recumbent bicycle) because they worry it will make the child stand out more. It's helpful to weigh the perceived costs (not financial) against the benefits for the child. Children can be very accepting of others; often the prejudice lies with adults, not with children.

Exercise and physical activity tips for the older child, adolescent, and adult

- For all types of exercise, an appointment with a physical therapist, occupational therapist, or a recreational therapist, is very useful. There are also wonderful athletic trainers who have advanced training in working with people with physical limitations. Trainers who lack this specialized training, however, may advise overexercising, which can lead to injuries. Consider calling the fitness centers or gyms in your area to check if any of their staff have training in adapting exercise programs for people with physical challenges.
- Expert guidance is recommended before working with weights. An experienced trainer or therapist can provide guidance on how much weight is safe and how many repetitions to perform.
- Fast walking can achieve many of the same benefits as running and may be safer for some people.

- Cycling offers many options, including outdoor and indoor (static) bikes. Three-wheeled bikes may be ideal for those with balance issues. An outdoor bike can be converted to an indoor (static) bike with the purchase of blocks (trainers) for that purpose. This is a great way to keep cycling when the weather doesn't allow for outdoor mobility.
- A therapist can offer guidance on the appropriate size and type of sports wheelchair to use and can advise on possible funding aid to purchase one.
- Swimming is an excellent option. A few tips for swimming:
    - Consider scheduling a few sessions with a physical, occupational, or recreational therapist to develop an appropriate swimming program.
    - Wheelchair users can call local pools to find one with PVC pool chairs and a ramp.
    - A pool with water temperature of 88 to 94 °F (31 to 34 °C) can be very therapeutic and can help reduce pain and stiffness.
    - Nonskid pool shoes are recommended for walking from the changing room to the pool and back to avoid falls on wet pool decks.
    - Swim paddles, kickboards, flippers, etc. can be used to increase resistance for muscle strengthening.
- Excellent videos online are available for exploring various activities such as adaptive yoga, tai chi, and more. The National Center on Health, Physical Activity, and Disability (nchpad.org) is a good resource.
- Incorporate as much exercise as possible into the normal day (e.g., cycling to school, after-school activities, work).
- Most school programs include at least a weekly session of physical education. Try to ensure that the program includes the child's or adolescent's needs as much as possible so they can participate, even if this means adapting the rules, the equipment, or the mindset of the teacher or coach. Forcing a child or adolescent to sit out their school physical education period is a missed opportunity both in terms of the benefits of exercise and the camaraderie and social experience of teamwork. Research has shown that school-based exercise programs are beneficial for children and adolescents with CP.

Appendix 6

Rehabilitation after selective dorsal rhizotomy

Table A6.1 describes rehabilitation post-selective dorsal rhizotomy (SDR) at Gillette Children's. Rehabilitation protocols vary between centers; your center will provide you with a rehabilitation plan.

Table A6.1 Rehabilitation post-selective dorsal rhizotomy (SDR)

Acute hospital stay (0–3 days post-surgery)	• Children wear knee immobilizers to help manage leg spasms. • Children are monitored for bladder changes in addition to pain in the early days. Bladder changes are relatively uncommon and typically resolve during the hospital stay. • Children are on flat bed rest for the first three days after surgery. Doctors/nurses direct pain management.
Inpatient rehabilitation (4–6 weeks post-surgery)	• Children are admitted to inpatient rehabilitation (rehab). • The inpatient rehabilitation team includes the following specialists: PM&R physician, nurse, physical therapist, occupational therapist, recreational therapist, psychologist, social worker, and child life specialist. • Children participate in therapies for at least three hours per day. • Children also use equipment (prone cart, wheelchair, mobile prone stander) for positioning and strengthening. • Emphasis is on developing new patterns for movement now that spasticity has been reduced. • At the time of discharge home, children are generally pain-free but may need additional help with mobility. Most children use a wheelchair. • Children are able to return to school full-time at the time of their discharge home.
Outpatient rehabilitation (up to 1 year)	• PT five times per week for one month and then at decreasing frequency based on the child's progress. • Emphasis is on continued strengthening, gross motor activities, balance, and gait training. • There is a gradual return to independent mobility and baseline walking function. • Children also continue with a home program for functional mobility, strengthening, and positioning. Most children do not have outpatient OT related to SDR.
Follow-up	• Follow-up with PMR, orthopedics, PT and 3D computerized motion analysis. Recommendations for additional treatment are based on the results of evaluation.

Appendix 7

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 A7.1.

Figure A7.1 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 A7.2.

Figure A7.2 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 A7.3.

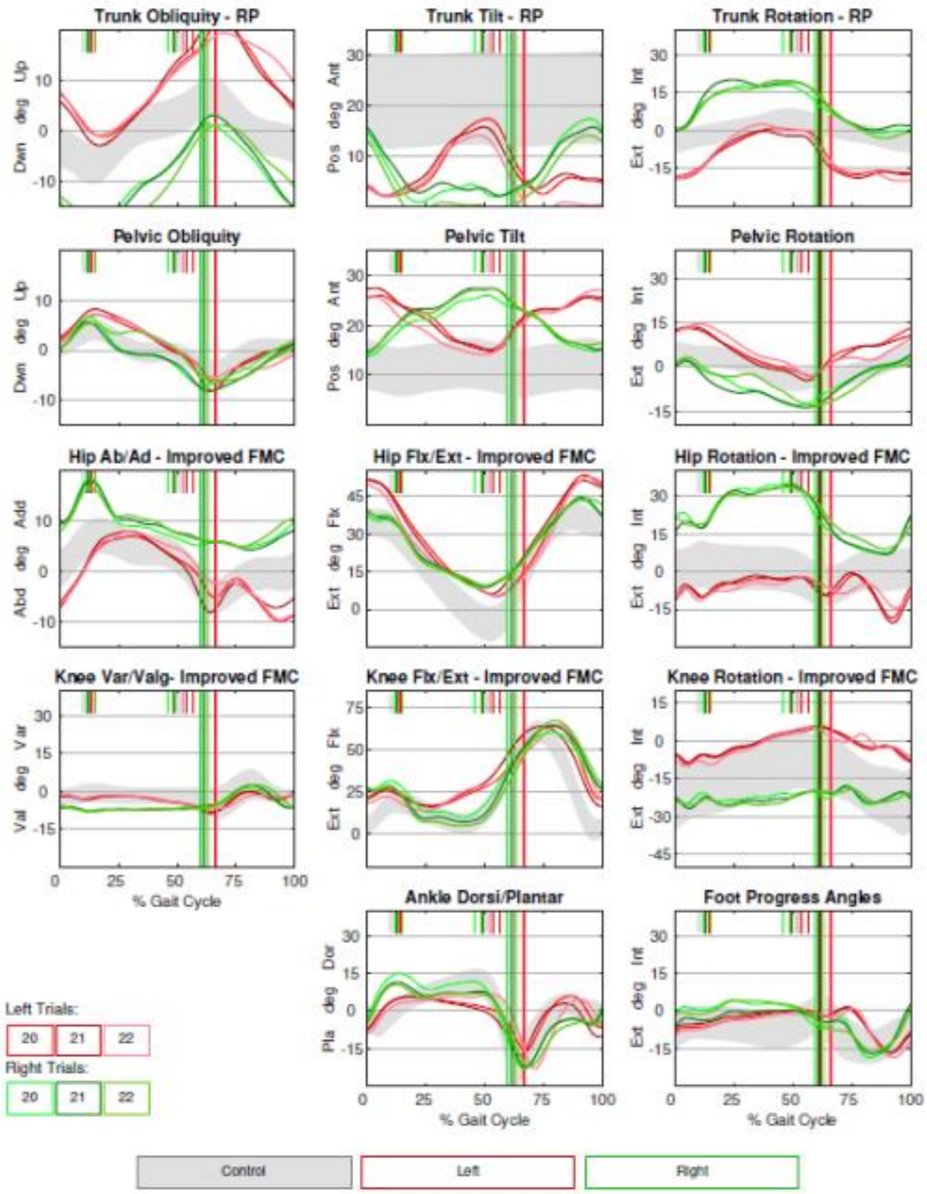

Figure A7.3 Kinematic graphs.

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 A7.4.

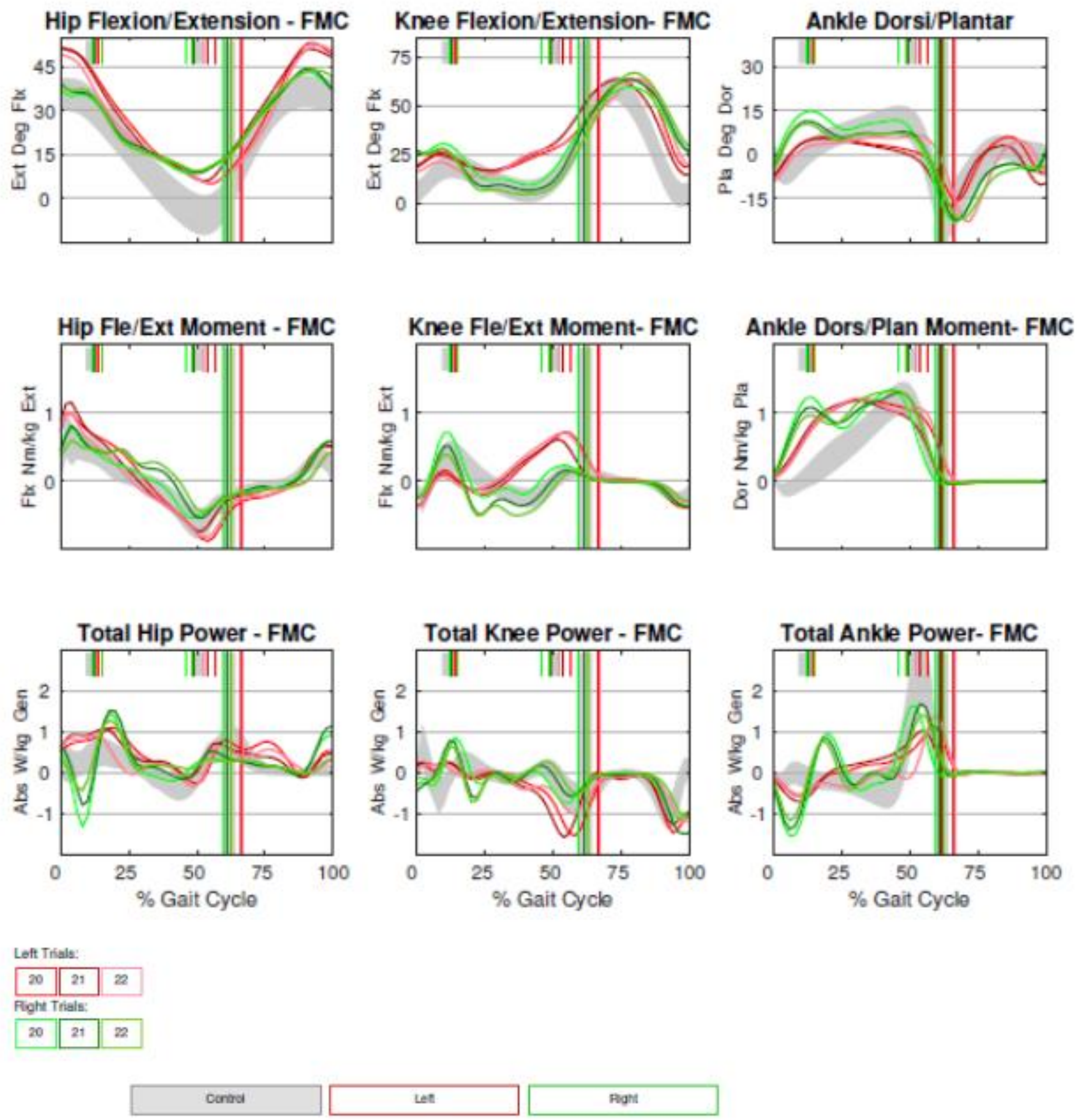

Figure A7.4 Kinetic graphs.

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 A7.5.

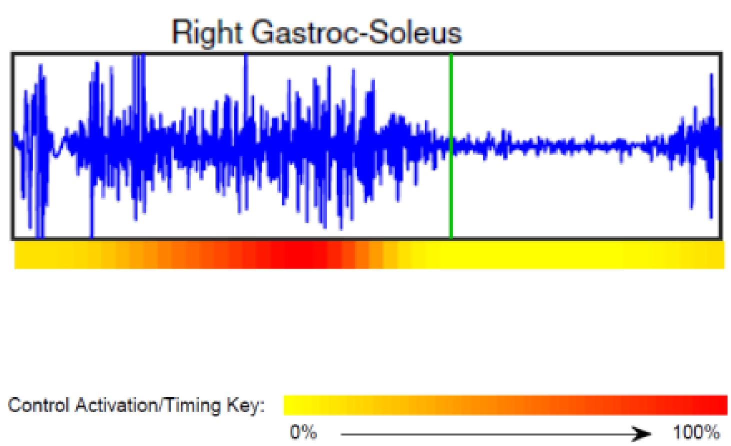

Figure A7.5 EMG graph.

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 A7.6.

Figure A7.6 Testing foot pressure.

Figure A7.7 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.

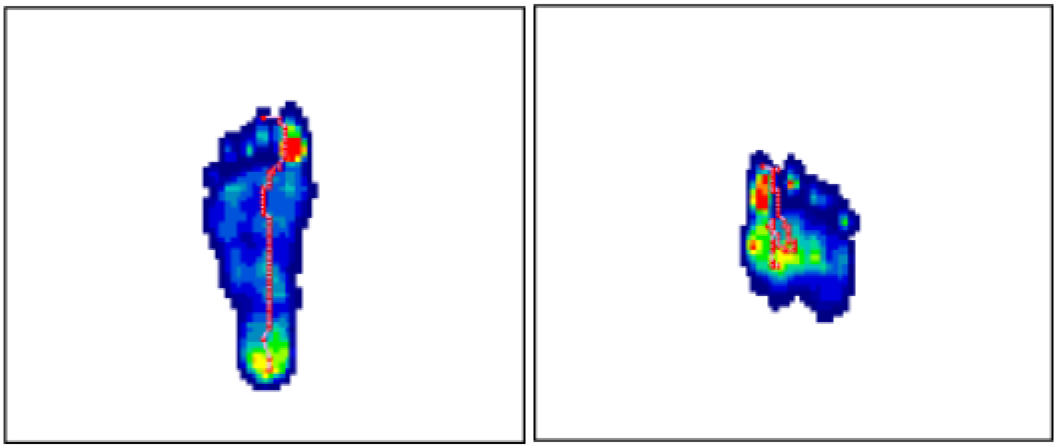

Figure A7.7 Plantar pressure graphs of left and right sides.

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 A7.8.) They then walk for six minutes to measure their movement energy expenditure.

Figure A7.8 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.

Appendix 8

Rehabilitation after single-event multilevel surgery

Gillette Children's has prepared an overview here of the stages of rehabilitation to expect after SEMLS:

The following two references provide more detail:

Van Bommel EEH, Arts MME, Jongerius PH, Ratter J, Rameckers EAA (2019) Physical therapy treatment in children with cerebral palsy after single-event multilevel surgery: A qualitative systematic review. A first step towards a clinical guideline for physical therapy after single-event multilevel surgery. *Ther Adv Chronic Dis*, 10, 1–14. Available here.

Colvin C, Greve K, Lehn C, et al. (2019) Evidence-based clinical care guideline for physical therapy management of single event multi-level surgeries (SEMLS) for children, adolescents, and young adults with cerebral palsy or other similar neuromotor conditions [pdf]. [online] Available here. (Scroll down under the evidence-based care guidelines for SEMLS.)

Appendix 9

Epilepsy management

Epilepsy management is complex. Epilepsy may evolve over time as the individual gets older, so the evaluation of the condition and its management is ongoing. Since clinical expertise can vary, it is important to know that information about management in this book may be different to practice at different hospitals and treatment centers. Management is not "one size fits all"; it must be customized.

The main goal of epilepsy management is to *prevent, reduce,* or *stop* seizures. Some related Important terms to understand include:

- **Seizure control:** Effective epilepsy management that results in a decrease in frequency, severity, and/or duration of seizures.
- **Seizure freedom:** A set period without any seizures; the ultimate goal of epilepsy management.
- **Remission:** A state where an individual with epilepsy is seizure-free for at least six months.
- **Resolved:** A state where an individual with epilepsy has remained seizure-free for the last 10 years, with no antiseizure medications for the last 5 years, or the individual had an age-dependent epilepsy syndrome and is past the applicable age for this diagnosis (i.e., self-limited neonatal or infantile epilepsy syndromes).

Why manage epilepsy?

Management of epilepsy is important for the following reasons:

- **To protect the brain from damage:** Epileptic seizures may lead to damage of areas in the brain, especially when they are prolonged or uncontrolled.
- **To protect organs and body systems from damage:** Epileptic seizures (especially those with motor signs) may lead to injuries and lesions in various body organs (e.g., kidneys or liver), or body systems (e.g., cardiovascular or musculoskeletal systems).
- **To prevent status epilepticus:** This condition, in which seizures last more than five minutes or occur in close succession (one after the other, without a return to baseline), is life-threatening.
- **To prevent SUDEP (sudden unexpected death in epilepsy):** This rare complication of epilepsy is named to describe the death of an individual with epilepsy when no other cause of death can be found.
- **To ensure safety and prevent injury:** Individuals with epilepsy are at an increased risk of accidental injuries from falls, motor vehicle accidents, and accidents around water, fire, and in other activities.
- **To improve quality of life:** Seizure control correlates with the ability to participate fully in life, including social activities, physical activities, education, employment, driving, and independent living.

How is epilepsy managed?

The management of epilepsy generally includes:

- **Pharmaceutical treatments**, involving the use of antiseizure medications, either as monotherapy (one medication) or polytherapy (more than one medication).

- **Non-pharmaceutical treatments**, involving the ketogenic diet, neuromodulation (repetitive electrical discharges administered through a device), and epilepsy surgery
- **Other medications or supplements**, including vitamins or medical cannabis

Pharmaceutical treatments are generally tried first. However, some epilepsy syndromes and drug-resistant epilepsy are best managed with non-pharmaceutical treatments or other medications or supplements. Pharmaceutical treatments, non-pharmaceutical treatments, and other medications or supplements can be used with the same individual and at the same time.

Management options for epilepsy are shown in Table A9.1.

Table A9.1 Management options for epilepsy

<table>
<tr><th>Management</th><th>Description</th><th>Indications for use</th></tr>
<tr><td colspan="3">Pharmaceutical treatments</td></tr>
<tr><td>Monotherapy</td><td>One antiseizure medication (may try a different medication if the first doesn’t work)</td><td>All types of epilepsy, generally tried first</td></tr>
<tr><td>Polytherapy</td><td>More than one antiseizure medication given at the same time (may try different combinations)</td><td>All types of epilepsy, when monotherapy does not work</td></tr>
<tr><td colspan="3">Non-pharmaceutical treatments</td></tr>
<tr><td>Ketogenic diet</td><td>Specialized diet with a very low amount of carbohydrates</td><td rowspan="3">Used when polytherapy does not work, or when the epilepsy type, epilepsy cause, or epilepsy syndrome is more responsive to non-pharmaceutical management</td></tr>
<tr><td>Neuromodulation</td><td>Repetitive electrical discharges administered through a device (for the management of epilepsy, these devices are surgically implanted)</td></tr>
<tr><td>Epilepsy surgery</td><td>Surgery to areas of the brain where seizures are thought to start or spread to</td></tr>
<tr><td colspan="3">Other medications and supplements</td></tr>
<tr><td>Medications</td><td>Medications other than antiseizure medication include:
• Immunotherapies (treatments that alter the immune system),
• Steroids (medications with anti-inflammatory properties)
• ACTH (a type of hormone therapy).</td><td>Used when the epilepsy type, epilepsy cause, or epilepsy syndrome is known to be responsive to a particular medication</td></tr>
<tr><td>Vitamins</td><td>Dietary supplements</td><td>Used in epilepsy syndromes known to be responsive to a particular vitamin</td></tr>
<tr><td>Medical cannabis</td><td>A pharmaceutical form of the cannabis plant.</td><td>Used in epilepsy types and epilepsy syndromes known to be responsive to cannabis</td></tr>
</table>

More information on epilepsy is available in the book *Epilepsy* in the **Gillette Children's Healthcare Series.**