Examination of the Child with Cerebral Palsy

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CLINICAL EVALUATION
To prepare treatment plans and accurately assess outcomes of treatment of children with cerebral palsy (CP), a balanced combination of medical history, detailed physical examination, functional assessment, imaging, observational gait analysis, computerized gait analysis, and assessment of patient and family goals must be interpreted.

THE MEDICAL HISTORY
The medical history should include a collection of information regarding birth history, developmental milestones, medical problems, surgical history, current physical therapy treatment, and current medication. Treatment plans depend on parent report of current functional walking level at home, school, and in the community, as well as other functional skills such as stair climbing, jumping, and running.

Birth history and other medical problems are important pieces of information for accurate diagnosis, future prognosis, treatment, and goal setting. Developmental milestones give information regarding the maturity of a skill such as walking and provide insight into the child’s future capacity. When considering surgical treatment, it is important to obtain the operative reports of previous surgeries to accurately assess current deformities and compensations. For example, iatrogenic weakness of the soleus muscle caused by heel cord lengthening may require a different treatment plan than primary soleus weakness.

Besides the medical history, the reason for referral and current surgical or treatment considerations are helpful. Complaints of pain, and behavior or learning issues assist the clinician in performing a good evaluation.

FUNCTIONAL OUTCOME MEASURES
Current level of function can be assessed using tools such as the Functional Assessment Questionnaire (FAQ),1 the Pediatric Orthopaedic Society of North America (Pediatric) Outcomes Data Collection Instruments (PODCI),2 or the evaluative Functional Mobility Scale (FMS).3 The FAQ is a validated 10-level parent report of ambulation. A child who is typically able to keep up with peers is scored at level 10; the scale decreases with decreasing ability for community ambulation. A companion FAQ-22 can be used to report other functional skills related to ambulation such as stair climbing, running, and encountering obstacles in the community such as curbs. The PODCI is also a validated parent report instrument designed to be used across ages and musculoskeletal disorders to assess functional health outcomes. It measures outcomes that can be affected by orthopedic treatment, and includes measures of upper and lower extremity motor skills, relief of pain, and restoration of activity. Correlations have been found between the FAQ, PODCI, and gait measures in children. When used in conjunction with gait data, they provide a more complete survey of change.4 The FMS is an evaluative
measure of functional mobility in children with CP aged 4 to 18 years. It quantifies functional mobility at both the activity level and participation domains of the International Classification of Functioning, Disability and Health. A unique feature of the FMS is reporting assistive device use in various environmental settings. The FMS has been shown to have adequate sensitivity to measure change after orthopedic intervention in children with CP.

**PHYSICAL EXAMINATION**

The standard physical assessment form used in the motion analysis laboratory at Gillette Children’s Specialty Healthcare provides a useful reference to a comprehensive physical examination (Fig. 1).

The physical examination can be separated into 7 broad categories:

1. Strength and selective motor control of isolated muscle groups
2. Degree and type of muscle tone
3. Degree of static muscle and joint contracture
4. Torsional and other bone deformities
5. Fixed and mobile foot deformities
6. Balance, equilibrium responses, and standing posture
7. Gait by observation.

Of course, physical examination is crucial, but its limitations in developing a plan for intervention must be recognized. The information collected during a physical examination is based on static responses, whereas functional activities, such as walking, are dynamic. Gait analysis data cannot be predicted by any combination of physical examination measurements either passive or active; however, there is a moderate correlation between time and distance parameters and strength and selectivity measures. The independence of gait analysis and physical examination measures supports the notion that each provides information that is important in the delineation of problems of children with CP. Numerous investigators have reported the lack of correlation between crouch gait and hamstring contracture identified by popliteal angle, for example. The method of assessment, the skill of the examiner, and the participation of the child can all affect the validity and reliability of the examination. The degree of tone can change with the position of the child, whether they are moving or at rest, the level of excitement or irritability, or the time or day of the assessment. Objective evaluation of muscle strength is difficult in small children and children with neurologic impairments. In addition, motor control and the assessment of movement dysfunction are subjective and rely heavily on the experience and expertise of the examiner.

**MUSCLE STRENGTH**

Strength evaluation is necessary to assess appropriateness for interventions such as selective dorsal rhizotomy or lower extremity surgery. Children with CP are weak. Motor function and strength are directly related. Manual muscle testing (MMT) using the Kendall scale is the typical method for measuring muscle strength in children with CP. Isometric assessment with a dynamometer is becoming more common in the clinic, and is often used in research and outcome studies. Isokinetic evaluations are used when evaluating strength throughout the range of motion (ROM).

The 5-point Kendall scale provides an easy and quick way to assess a child for significant weakness or muscle imbalance, and requires only a table and standardized positioning. However, it does rely heavily on the examiner’s judgment, experience, the amount of force generated by the examiner, and the accuracy of the positioning of the patient. Small yet clinically significant differences in strength may not be detected using this method. It is subjective and prone to examiner bias. However, under strict evaluation protocols, this method is useful. For children who are less than the age of 5 years, and who cannot follow complex directions for maximal force production, the MMT method, as well as any other method of strength assessment, should be considered a screening tool at best.

Because of the wide variation that is seen with manual muscle assessment of isometric strength, the use of a hand-held dynamometry (HHD) has increased in the clinic and in research protocols to better quantify strength variation. The HHD approach has been shown to be a valid and reliable tool to measure isometric strength in patients with brain lesions and in children with CP. However, it has an upper limit, and exceeds that limit when used with stronger patients. Strength profiles for children with CP and normative data for young children have been published. Validity of this examination still depends on appropriate positioning, whether stabilization is used, and the experience of the tester. Normalization is required for body weight and lever length for strength comparisons.

Isokinetic strength assessment is used to measure torque generated continuously through an arc of movement. The length of time required...
Fig. 1. The standard physical assessment form used in the James R Gage Center for Gait and Motion Analysis at Gillette Children's Specialty Healthcare.
for this assessment, the expense and lack of portability of the equipment, and the difficulties young children have complying with this test modality have limited the incorporation of isokinetic strength testing in the pediatric clinical setting.

SELECTIVE MOTOR CONTROL

Impaired ability to isolate and control movements confounds strength assessment and contributes to ambulatory and functional motor deficits. Assessment of selective motor control involves isolating movements on request, appropriate timing, and maximal voluntary contraction without overflow movement. A typical scale for muscle selectivity reports 3 grades of control: 0, no ability; 1, partial ability; and 2, complete ability to isolate movement. The detailed definitions and descriptions for the lower extremity muscles groups assist in accurately describing a patient’s motor control and are always reported together with strength (Table 1).

During static physical examination, a child with hemiplegia may not be able to actively dorsiflex the ankle on the involved side without a mass flexion pattern including hip and knee flexion. On examination muscle strength of 3/5 (3 out of 5), with a selectivity grade of 0/2 (0 out of 2) is identified. While walking this child may have difficulty with clearance of their foot in early swing phase because of the inability to perform dorsiflexion with the hip in extension. However, in midswing, dorsiflexion with inversion could occur because of the child’s inability to regulate the pull of the anterior tibialis and the extensor digitorum longus. In this situation, adequate dorsiflexion occurs, but the timing is late and the motion is not controlled. No surgical treatment would be able to address the problems of timing and balance. An orthotic may be the more appropriate recommendation.

MUSCLE TONE ASSESSMENT

Tone is the resistance to passive stretch while a person is attempting to maintain a relaxed state of muscle activity. Hypertonia has been defined as abnormally increased resistance to an externally imposed movement about a joint. It can be caused by spasticity, dystonia, rigidity, or a combination of these features. Resting muscle tone can be influenced by the degree of cooperation, apprehension, or excitement present in the patient as well as the position during the assessment. Time spent playing or talking with the child before and during the examination often helps with the accuracy of the examination. Muscle tone assessment on different occasions by different practitioners may be necessary to accurately characterize the nature of the child’s muscle tone. Standardization within a facility for testing positions and the use of a grading scale are imperative. Sanger and colleagues recommend this process: start by palpating the muscle in question to determine if there is a muscle contracture at rest. Next, move the limb slowly to assess the available passive ROM. The limb can then be moved through the available range at different speeds to assess the presence or absence of a catch and how this catch varies with a variety of speeds. Next, change the direction of motion of the joint at various speeds and assess how the resistance (including timing) varies. Last, observe the limb/joint while asking the patient to move the same joint on the contralateral side. Observe and document any involuntary movement or a change in the resistance to movement on the side being assessed. By using a standard process for evaluation, the consistency and completeness of tone abnormality documentation improve.

Spastic (compared with dystonic) hypertonia causes an increase in the resistance felt at higher speeds of passive movement. Resistance to externally imposed movement rises rapidly above a speed threshold (spastic catch). The Ashworth scale, modified Ashworth scale, Tardieu scale, and an isokinetic dynamometer in conjunction with surface electromyography are methods used to assess severity of spastic hypertonia.

On the other hand, dystonic hypertonia shows an increase in muscle activity when at rest, has a tendency to return to a fixed posture, increases resistance with movement of the contralateral limb, and changes with a change in behavior or posture. There are also involuntary sustained or intermittent muscle contractions causing twisting and repetitive movements, abnormal postures, or both. The Hypertonia Assessment Tool (HAT) is a tool developed to distinguish between spasticity, dystonia, and rigidity in the pediatric clinical setting (Fig. 2). The reliability and validity for spasticity and rigidity is good, but only moderate for dystonia and mixed tone. The Barry Albright Dystonia (BAD) scale, a 5-point ordinal scale, is another measure of generalized dystonia. Mixed tone is often identified with a combination of both types of hypertonicity in the same patient. Mixed tone is more difficult to diagnose and quantify than pure spasticity. However, in children with CP, it is important to assess the degree of mixed tone present, because the outcome of surgery may be less predictable.
**ROM AND CONTRACTURE**

Variation in ROM measurements between observers is common and frustrating. These errors are most likely the result of how much stretch is applied before recording the value for the range of movement. Should it be a little (when resistance is first felt) or a lot (to patient tolerance)? Cusick\(^{28}\) states that the findings pertaining to the initial end point are more significant to functional ability than the stretched end-point findings.

Differentiation between static and dynamic deformity may be difficult in the nonanesthetized patient.\(^{29}\) However, static examination of muscle length provides some insight into whether contractures are static or dynamic. Because of the velocity-dependent nature of spasticity, it is important that assessment of ROM is performed slowly. However, comparison of joint ROM with slow and rapid stretch can be useful in the evaluation of spasticity.\(^{30}\) Dynamic contracture disappears under general anesthesia. Thus the ROM examination under general anesthesia can be used to help decide whether to inject botulinum toxin to address spasticity in a muscle or perform surgery to lengthen a contracture of the tendon.

Differentiation between contracted biarticular and monoarticular muscles is important. The Silverskioärd test ([Fig. 3](#)) assesses the difference between gastrocnemius and soleus contracture. The Duncan-Ely test ([Fig. 4](#)) differentiates between contracture of the monoarticular vasti and the biarticular rectus femoris. However, Perry and colleagues\(^{31}\) have shown that when these tests are performed in conjunction with fine-wire electromyography, both the monoarticular and the biarticular muscles crossing the joint contract. For example, in the nonanesthetized patient, the Duncan-Ely test induces contraction of not only the rectus femoris but also the iliopsoas, and the Silverskioärd test induces contraction of both the gastrocnemius and the soleus. However, under general anesthesia these biarticular muscle tests reliably differentiate the location of the contracture. Consequently, they should routinely be included as part of the presurgical examination under anesthesia.

**Hip**

The Thomas test is used to measure the degree of hip flexor tightness. It is performed with the patient in a supine position and the pelvis held such that the anterior superior iliac spine (ASIS) and the posterior superior iliac spine (PSIS) are aligned vertically. Defining the pelvic position consistently rather than using the flatten-the-lordosis method improves reliability. Because of the origin and insertion points, the cause of limited hip abduction ROM can be distinguished by measuring hip abduction in various positions of the hip and knee with the patient supine. The one-joint adductors (adductor longus, brevis, and magnus) are isolated with the knee flexed. In this position, the gracilis is relaxed. With the knee in full extension the length of the 2-joint gracilis is in a position of maximum stretch. If hip abduction is more limited when the knee is extended compared with the knee flexed, contracture of the gracilis is the cause. Controlling and stabilizing pelvic position is imperative for a correct measurement of hip ROM.

**Knee**

In children with CP, capsular contracture causes knee flexion contracture. It is imperative to differentiate between true knee joint contracture and hamstring contracture. Knee joint contracture is identified if knee extension is limited with the hip in extension (to relax the hamstrings) and the ankle relaxed in a position of equinus (to relax the gastrocnemius). Hamstring contracture is identified if knee extension is limited when the hip is flexed 90° (the popliteal angle). Normal values for popliteal angle are age and gender dependent, with boys tighter than girls and both tighter with increasing age, especially around the time of the adolescent growth spurt. Like the test for hip flexion contracture, it is important to control pelvic position (the line connecting the ASIS and PSIS vertical) when assessing hamstring length. In the patient’s normal resting supine position, a hip contracture causes lumbar lordosis and anterior pelvic tilting that shifts the origin of the hamstrings on the ischial tuberosity proximally. The contralateral hip is in full extension, whereas the ipsilateral hip is flexed to 90°. The measurement of the degrees lacking from full extension is recorded as the unilateral popliteal angle ([Fig. 5A](#)). The bilateral popliteal angle measurement is performed with the contralateral hip flexed until the ASIS and PSIS are aligned vertically (comparable with the test for hip flexion contracture described earlier) (see [Fig. 5B](#)). A significantly smaller popliteal angle with the pelvic position corrected is referred to as a hamstring shift. The value of the popliteal angle with a neutral pelvis is a measure of the true hamstring contracture and the value with the lordosis present is the functional hamstring contracture. The difference between the 2 represents the degree of hamstring shift.

Hamstring contracture is frequently implicated as a cause of crouch gait. However, increased anterior pelvic tilt is common in crouch gait caused
## Table 1
Selective motor control grading scale description

### Definitions of Selective Motor Control

<table>
<thead>
<tr>
<th>Movement</th>
<th>Position</th>
<th>2: hip flexion in a superior direction without evidence of adduction, medial or lateral rotation, or trunk extension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip Flexion</td>
<td>Patient seated supported or unsupported with hips at a 90° angle, legs over the side of the table. Arms folded across chest or resting in lap (not on the able or hanging on to the edge)</td>
<td>1: hip flexion associated with adduction, medial or lateral rotation, or trunk extension that is not obligatory but occurs in conjunction with the desired motion through at least a portion of the ROM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0: hip flexion that occurs only with obligatory knee flexion, ankle dorsiflexion, and adduction</td>
</tr>
<tr>
<td>Hip Extension</td>
<td>Patient lying prone, head resting on pillow (prone on elbows not allowed). Knees in maximum possible extension. Pelvis stabilized as necessary</td>
<td>2: hip extension in a superior direction without evidence of medial or lateral rotation, trunk extension, or abduction</td>
</tr>
<tr>
<td>(Hamstrings plus Gluteus Maximus)</td>
<td></td>
<td>1: hip extension associated with medial or lateral rotation, trunk extension, or abduction that is not obligatory but occurs in conjunction with the desired motion through at least a portion of the ROM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0: hip extension that occurs only with obligatory trunk extension, arm extension, or neck extension. May also include medial or lateral rotation, or abduction</td>
</tr>
<tr>
<td>Hip Abduction</td>
<td>Side-lying, the hip in neutral or slight hip extension, neutral medial or lateral rotation, knee in maximum possible extension. Pelvis stabilized as necessary</td>
<td>2: hip abduction in a superior direction without evidence of medial or lateral rotation or hip flexion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: hip abduction in a superior direction associated with hip flexion, or medial or lateral rotation that is not obligatory but occurs in conjunction with the desired motion through at least a portion of the ROM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0: hip abduction that occurs with obligatory hip flexion, or medial or lateral rotation</td>
</tr>
<tr>
<td>Knee Extension</td>
<td>Patient seated supported or unsupported with hips at a 90° angle, knees at 90° angle resting over the side of the table. Thigh stabilized as necessary</td>
<td>2: knee extension in a superior direction, without evidence of hip or trunk extension, medial or lateral rotation of the thigh or hip flexion</td>
</tr>
</tbody>
</table>

(continued on next page)
Table 1 (continued)

<table>
<thead>
<tr>
<th>Definitions of Selective Motor Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: knee extension associated with hip or trunk extension, hip flexion, or medial or lateral rotation of the thigh that is not obligatory but occurs in conjunction with the desired motion through at least a portion of the ROM</td>
</tr>
<tr>
<td>0: knee extension that occurs with obligatory hip or trunk extension, hip flexion, or medial or lateral rotation of the thigh</td>
</tr>
</tbody>
</table>

Knee Flexion

Position: patient lying prone, head resting on pillow (prone on elbows not allowed). Knees in maximum possible extension. Pelvis and thigh stabilized as necessary

2: knee flexion in a superior direction without evidence of hip flexion, medial or lateral thigh rotation, or tilting, rotation of the pelvis, or ankle plantarflexion

1: knee flexion associated with a pelvic rise, hip flexion, medial or lateral rotation of the thigh, or ankle plantarflexion that is not obligatory but occurs in conjunction with the desired motion through at least a portion of the ROM

0: knee flexion that occurs with obligatory hip flexion, pelvic tilting or rotation, medial or lateral rotation of the thigh or ankle plantarflexion

Ankle Dorsiflexion (Anterior Tibialis)

Position: patient seated supported or unsupported with hips at a 90° angle, knees in extension (flexion may be allowed to achieve a range of dorsiflexion). Lower leg supported. Thigh stabilized as necessary

2: ankle dorsiflexion and inversion without evidence of increased knee flexion, subtalar eversion, or extension of the great toe

1: ankle dorsiflexion and inversion associated with increased knee flexion, subtalar eversion, or extension of the great toe that is not obligatory but occurs in conjunction with the desired motion through at least a portion of the ROM

0: ankle dorsiflexion and inversion that occurs with obligatory knee flexion, subtalar eversion, or extension of the great toe

Ankle Plantarflexion (Soleus)

Position: patient lying prone, head resting on pillow (prone on elbows not allowed). Knees in 90° of flexion. Lower leg stabilized proximal to the ankle as necessary. Ankle in neutral plantarflexion/dorsiflexion position

2: ankle plantarflexion in a superior direction without evidence of knee extension, subtalar inversion, eversion, or toe flexion

1: ankle plantarflexion associated with knee extension, subtalar inversion, eversion, or toe flexion that is not obligatory but occurs in conjunction with the desired motion through at least a portion of the ROM

0: ankle plantarflexion that occurs with obligatory knee extension, subtalar inversion, eversion, or toe flexion

Ankle Plantarflexion (Gastrocnemius)

Position: patient lying prone, head resting on pillow (prone on elbows not allowed). Knees in maximum extension, foot projecting over the end of the table. Lower leg stabilized proximal to the ankle as necessary. Ankle in neutral plantarflexion/dorsiflexion position

2: ankle plantarflexion in a superior direction without evidence of subtalar inversion, eversion, or toe flexion

1: ankle plantarflexion associated with subtalar inversion, eversion, or toe flexion that is not obligatory but occurs in conjunction with the desired motion through at least a portion of the ROM

0: ankle plantarflexion that occurs with obligatory subtalar inversion, eversion, or toe flexion

Ankle Inversion (Posterior Tibialis)

Position: patient seated supported or unsupported with hips at a 90° angle, thigh in lateral rotation, knees in flexion with lower leg stabilized proximal to the ankle. Ankle in neutral plantarflexion/dorsiflexion position

2: inversion at the STJ with plantarflexion of the ankle without evidence of toe flexion

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by CP. Like the supine examination for hamstring contracture described earlier, this produces a hamstring shift,\textsuperscript{32-34} In this situation, hamstring length may be normal or even long, and hamstring lengthening surgery weakens hip extension and exacerbates the excessive hamstring length. Anterior pelvic tilt and lumbar lordosis may be worsened with variable improvement in crouch gait. Because of the relative length of the hamstring moment-arm at the hip and knee, Delp and colleagues\textsuperscript{32} have estimated that for every 1° of excessive pelvic lordosis, there is a 2° increase in knee flexion. A hamstring shift greater than 20° usually indicates excessive anterior tilt.

### Table 1 (continued)

<table>
<thead>
<tr>
<th>Definitions of Selective Motor Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: inversion at the STJ with plantarflexion of the ankle associated with toe flexion that is not obligatory but occurs in conjunction with the desired motion through at least a portion of the ROM</td>
</tr>
<tr>
<td>0: inversion at the STJ with plantarflexion of the ankle that occurs with obligatory and forceful toe flexion</td>
</tr>
</tbody>
</table>

**Ankle Eversion (Peroneus Brevis plus Peroneus Longus)**

Position: patient seated supported or unsupported with hips at a 90° angle, thigh in medial rotation, knees in flexion with lower leg stabilized proximal to the ankle. Ankle in neutral plantar/dorsiflexion

| 2: eversion at the STJ with plantarflexion of the ankle without evidence of toe flexion. If head of first metatarsal is depressed action of the peroneus longus is indicated |
| 1: eversion at the STJ with plantarflexion of the ankle associated with toe flexion that is not obligatory but occurs in conjunction with the desired motion through at least a portion of the ROM |
| 0: eversion at the STJ with plantarflexion of the ankle that occurs with obligatory and forceful toe flexion |

**Ankle Eversion (Peroneus Tertius)**

Position: patient seated supported or unsupported with hips at a 90° angle, knees in flexion with lower leg stabilized proximal to the ankle. Ankle in neutral plantar/dorsiflexion

| 2: eversion at the STJ with dorsiflexion of the ankle and 2- to 5-toe extension |
| 1: not applicable |
| 0: not applicable (peroneus tertius and extensor digitorum longus are anatomically combined; the 2 muscles always act together) |

**Great Toe Extension (Extensor Hallucis Longus)**

Position: patient seated supported or unsupported with hips at a 90° angle, knees in flexion with lower leg supported. Ankle in neutral plantar/dorsiflexion

| 2: extension of the metatarsophalangeal joint of the great toe without evidence of knee flexion or ankle dorsiflexion |
| 1: extension of the metatarsophalangeal joint of the great toe associated with knee flexion or ankle dorsiflexion that is not obligatory but occurs in conjunction with the desired motion through at least a portion of the ROM |
| 0: extension of the metatarsophalangeal joint of the great toe with obligatory knee flexion, or ankle dorsiflexion |

**Great Toe Flexion (Flexor Hallucis Longus)**

Position: patient seated supported or unsupported with hips at a 90° angle, knees in maximum extension with lower leg supported. Ankle in neutral plantar/dorsiflexion

| 2: flexion of the metatarsophalangeal joint of the great toe without evidence of knee extension or ankle plantarflexion |
| 1: flexion of the metatarsophalangeal joint of the great toe associated with knee extension or ankle plantarflexion that is not obligatory but occurs in conjunction with the desired motion through at least a portion of the ROM |
| 0: flexion of the metatarsophalangeal joint of the great toe with obligatory knee extension, or ankle plantarflexion |

either from tight hip flexor musculature, weak abdominals, or weak hip extensors.\textsuperscript{32} Normal popliteal angle measurements of a 5- to 18-year-old should be 0 to 49° for optimal functioning (mean 26°).\textsuperscript{35} A 50° popliteal angle is considered a mild deviation. Because of the difficulty in establishing dynamic hamstring length on physical examination and the danger of iatrogenic problems with inappropriate surgery, static hamstring length from supine physical examination should be supplemented by estimates of hamstring length.

Fig. 2. HAT is useful to determine the type of high muscle tone.

![Figure 2](image)

Examining the Child with Cerebral Palsy

<table>
<thead>
<tr>
<th>Items in Order of Administration</th>
<th>Type of Hypertonia</th>
<th>Head/Neck</th>
<th>Upper Extremity</th>
<th>Lower Extremity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Increased involuntary movements or postures of the designated limb with tactile stimulus of a distant body part.</td>
<td>Dystonia</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2. Increased involuntary movements or postures with purposeful movement of a distant body part.</td>
<td>Dystonia</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>3. Velocity dependent resistance to passive stretch.</td>
<td>Spasticity</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>4. Presence of a spastic catch</td>
<td>Spasticity</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>5. Equal resistance to passive stretch during bi-directional movement of a joint</td>
<td>Rigidity</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>6. Increased tone with movement of a distant body part</td>
<td>Dystonia</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>7. Maintenance of limb position after passive movement.</td>
<td>Rigidity</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Scoring:** check if present or absent

The Silversköld test. (A) The Silversköld test differentiates tightness of the gastrocnemius and the soleus. In this test, the knee is flexed to 90°, the hind foot is positioned in varus, and maximal dorsi-flexion obtained. (B) As the knee is extended, if the ankle moves toward plantar-flexion, contracture of the gastrocnemius is present. (From Gage JR, Schwartz MH, Koop SE, et al, editors. The identification and treatment of gait problems in cerebral palsy. London: Mac Keith Press; 2009. p. 191; with permission.)

![Figure 3](image)

The Duncan-Ely test. The patient is positioned prone. As the knee is flexed, a contracture of the rectus femoris causes the hip to flex because the rectus femoris is a hip flexor and knee extensor. (From Gage JR, Schwartz MH, Koop SE, et al, editors. The identification and treatment of gait problems in cerebral palsy. London: Mac Keith Press; 2009. p. 192; with permission.)

![Figure 4](image)
obtained from gait analysis before consideration of hamstring lengthening surgery.

**BONE DEFORMITY**

**Femoral Anteversion**

Femoral anteversion refers to the relationship between the axis of the femoral neck and the femoral condyles in the transverse plane. This alignment can be estimated in the prone position by rotating the hip internally and externally until the greater trochanter is felt to be maximally prominent laterally. In this position, the neck of the femur is horizontal (Fig. 6). When the knee is flexed 90°, the tibia is typically perpendicular to the posterior aspect of the femoral condyles. Femoral anteversion is reported as the difference between the tibia and the vertical. Average normal adult values are 10° for men and 15° for women. Femoral anteversion at birth is 45°. If growth and development are typical, most infantile anteversion remodels between 1 and 4 years of age, reaching adult normal values by age 8 years.

**Tibial Torsion**

Tibial torsion is more difficult to measure accurately regardless of experience. Three methods of clinical assessment are used. Thigh-foot angle may be most reliable because it is most commonly used (Fig. 7). However, hind- and midfoot mobility is necessary to properly align the foot in line with the talus primarily because it is difficult to standardize foot alignment, and foot deformities are common in children with CP. Through knee joint transverse plane rotation can also be inadvertently introduced. The bimalleolar axis method can be used particularly in cases of rigid foot deformity because alignment and position of the foot does not affect the measurement, but correct alignment of the knee joint and accurate identification of the axis of the malleoli is challenging (Fig. 8). The second-toe test is a third method. Developed at Gillette Children’s Specialty Healthcare, this test is favored by the authors because the starting position is with the knee in extension, the position of interest during ambulation and standing, unlike the thigh-foot angle and because the axis of the tibia is easier to visualize than the bimalleolar axis (Fig. 9). The second-toe test allows visualization of the foot progression angle with the knee extended. It eliminates the rotational component of knee movement, but requires that the foot be placed in subtalar neutral alignment. Therefore, in children with equinus contracture and/or severe varus or valgus foot deformities, this test cannot be performed accurately. Despite the absence of tibia torsion, the presence of a true knee valgus increases the measurement of the second-toe test by the amount of true valgus that is present. Given the significant effect of even minor degrees
of tibial torsion on lever arm dysfunction, these measures may not be accurate and reliable enough to guide the amount of surgical correction. Therefore, other methods of detection and measurement of tibial torsion are necessary. At Gillette Children’s Specialty Healthcare, we have also been relying on patient-specific data from motion analysis using functional model calibration (the difference between the functional knee and bimalleolar axes). Some centers rely on computed tomography scan measurement of tibial torsion.

**Patella Alta**

Patella alta is common in children with CP and is probably contributed to by the chronic excessive knee extensor forces of rectus femoris spasticity and crouch gait. These same forces may lead to inferior pole sleeve avulsion fractures. To screen for patella alta, the patient is positioned supine with the knees extended. The top of the patella is then palpated. The superior pole of the patella is typically one finger width proximal to the adductor tubercle. Patella alta may contribute to patellofemoral instability, pain, and subluxation. Patella alta can also be associated with terminal knee extensor dysfunction (quadriceps insufficiency) measured by extensor lag. Extensor lag is measured with the patient positioned supine (to relax the hamstrings), and the leg flexed at the knee over the end of the examination table. The child is asked to actively extend the knee as
much as possible. The extensor lag is recorded as the difference between the active range and the passive ROM. Patellar position can be measured with a lateral radiograph of the knee taken in full extension.

**Foot**

Pronation and supination are terms used to describe the triplanar motions in the foot and ankle. These 2 motions are pure rotations about an oblique axis, resulting in the same end position as 3 separate rotations in the cardinal planes. Although inconsistently used, the terms pronation and supination should be used only in reference to the triplane motions of the foot and ankle, because they provide a consistent and logical description of the motion that is anatomically available.

Despite the complexity of foot anatomy and biomechanics, evaluating the foot and understanding its function in both the nonweight-bearing and weight-bearing position is essential. The foot must function as both a mobile adaptor and a rigid lever at different points in the gait cycle.

**Fig. 8.** The bimalleolar axis angle. (A) With the knee fully extended in the supine position rotate the thigh segment until the medial and lateral femoral condyles are horizontal. (B) Mark the midpoints of the medial and lateral malleolus. (C) Using a goniometer or angle finder, measure the angle between the bimalleolar axis and the condylar axis. *(From Gage JR, Schwartz MH, Koop SE, et al, editors. The identification and treatment of gait problems in cerebral palsy. London: Mac Keith Press; 2009. p. 197; with permission.)*

**Fig. 9.** The second-toe test. (A) An external tibial torsion leads to an outwardly pointed foot when the patient is relaxed in the prone position with the knee fully extended. (B) Rotate the leg to position the second toe pointing directly toward the floor (in this case requiring internal hip rotation). (C) Hold the thigh in this position (preventing internal or external hip rotation) as the knee is flexed. Measure the angle from vertical. *(From Gage JR, Schwartz MH, Koop SE, et al, editors. The identification and treatment of gait problems in cerebral palsy. London: Mac Keith Press; 2009. p. 197; with permission.)*
Correctly identifying structural abnormalities in the nonweight-bearing position and the compensations that occur as a result of these abnormalities in weight bearing is essential to determining interventions to improve foot position and the function of the entire lower extremity.

Because every foot has its own neutral subtalar joint (STJ) position, the use of the nonweight-bearing STJ neutral (STJN) position provides consistency in positioning the foot in order to assess and identify patient-specific structural abnormalities and their resultant compensations in weight bearing. Root and colleagues originally defined STJN as the position from which the STJ can be maximally pronated and supinated, and, therefore, the position from which the STJ can function optimally. It is the position of the STJ where it is neither pronated nor supinated. In addition, determining STJN and then naming positions of the rearfoot and forefoot in relation to the next most proximal segment is consistent with the orthopedic naming of deformities in relation to the adjacent, proximal segment. This strategy allows the evaluator a starting point from which to describe compensations/deviations in the foot that may (or may not) occur when going from the nonweight-bearing to the weight-bearing position.

STJN is found through palpation at the articulation between the head of the talus and the navicular. Congruency of the talonavicular joint is the position of the foot at which neither the medial nor lateral head of the talus protrudes and the examiner feels symmetry of the navicular on the head of the talus. From this starting point, the patient’s rearfoot and forefoot relationships are evaluated. Further details regarding the method of finding STJN during physical examination have been published.

**Evaluation of the rearfoot position in STJN**

Once the foot has been placed in the STJN position, rearfoot position in relationship to the lower one-third of the leg is assessed. By visualizing the relationship of the bisector of the calcaneus relative to the bisector of the lower one-third of the leg, the rearfoot alignment can be described. If this relationship is linear, the rearfoot position is said to be vertical. If the orientation of the rearfoot with respect to the lower one-third of the leg is inverted, this position is known as a varus position of the rearfoot. If the line bisecting the calcaneus is everted in relation to the lower one-third of the leg, this position is referred to as a valgus position of the rearfoot.

**Evaluation of the forefoot position in STJN**

Once the rearfoot position has been determined, forefoot to rearfoot relationship can be evaluated in each of the 3 cardinal planes. While maintaining STJN, forefoot position in the frontal plane can be described by assessing the angle between a line that is perpendicular to the bisection of the posterior calcaneus (replicating the plane of the calcaneal condyles) and the plane of the metatarsal heads. In this position, if the plane of the metatarsal heads is in the same plane as the line that

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**Fig. 10.** Evaluation of rearfoot position in relationship to the lower leg in the STJN position. If the relationship is linear, the rearfoot position is described as being vertical (most common). If inverted, the rearfoot is said to be in a varus position, and if everted, the rearfoot is said to be in a valgus position (rare). (From Gage JR, Schwartz MH, Koop SE, et al, editors. The identification and treatment of gait problems in cerebral palsy. London: Mac Keith Press; 2009. p. 214; with permission.)
is perpendicular to the bisection of the calcaneus, the forefoot position is described as being neutral (Fig. 11). If the plane of the forefoot in relationship to the rearfoot shows the medial side of the foot to be higher than the lateral side (forefoot inverted) this position is described as forefoot varus deformity (Fig. 12). If the opposite is seen (i.e., the lateral border of the foot is higher than the medial border [forefoot everted]), this position is described as being a forefoot valgus deformity (Fig. 13). Typically, 2 types of forefoot valgus deformities exist. The first shows that all of the metatarsal heads are everted and is referred to as a total forefoot valgus. The second is caused by plantarflexion of the first ray (first cuneiform plus first MT), whereas the 2 to 5 metatarsal heads lie in the appropriate plane. The relationship of the forefoot to the rearfoot must also be assessed in the sagittal plane. If the examiner visualizes a plane representing the ground surface applied to the plantar surface of the calcaneus, the plantar surface of the metatarsal heads should also lie on this plane. If the plane of the metatarsals sits below that of the calcaneus, the forefoot would be described as being plantarflexed in relation to the rearfoot, often referred to as a forefoot equinus deformity. In the transverse plane, the typical relationship between the forefoot and rearfoot requires the forefoot to have the same longitudinal direction as the rearfoot. Deviations of the forefoot in the transverse plane toward the midline are referred to as adduction, and away from the midline as abduction.

**Compensations**

Compensation is a change in the structural alignment or position of the foot to neutralize the effect of an abnormal force, resulting in a deviation in structural alignment or position of another part. When structural deformities are present in the foot and ankle, as described earlier, the foot has the ability to compensate for these deformities. Most often, these compensations occur through the motion of the subtalar and the midtarsal joint. Over time, abnormal compensations can lead to tissue stress and pain, as well as create lever arm dysfunction, which negatively affects gait and posture.

**Forefoot varus**

The foot with a structural forefoot varus has an inverted orientation of the forefoot to the rearfoot when placed in the nonweight-bearing STJN position. To compensate for this deformity during gait, this foot type typically shows an abnormal amount of pronation during midstance, because, when the medial calcaneal condyle has reached the ground in midstance, the forefoot, rather than being in

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**Fig. 11.** Evaluation of the STJN forefoot position in the frontal plane. If the plane of the metatarsal heads lies in the same plane as a line that is perpendicular to the bisection of the calcaneus, the forefoot position is described as neutral. No compensation is required in the weight-bearing position. (From Gage JR, Schwartz MH, Koop SE, et al, editors. The identification and treatment of gait problems in cerebral palsy. London: Mac Keith Press; 2009. p. 215; with permission.)
contact with the floor, shows an orientation where the medial border of the foot is elevated from the ground surface. To assist with the medial border reaching the ground, the STJ (if pain and motion allow) continues pronating as the midstance phase of gait begins (see Fig. 12). This excessive pronation is an abnormal compensation, and is manifested as eversion of the calcaneus, abduction of the forefoot, and lowering of the medial longitudinal arch. This compensated foot position leads to internal malrotation of the entire lower extremity as the talus plantarflexes and deviates medially. The clinician must appreciate the influence that the forefoot deformity has on the position of not only the rearfoot but the entire lower extremity, and address treatment accordingly. Placing a wedge under the medial forefoot may correct the compensated position of the rearfoot, confirming that the rearfoot position is flexible and being driven by the forefoot deformity. If correction of the rearfoot is not seen, a fixed rearfoot deformity may be present. However, hypermobility of the midfoot and diminished motor control and strength can limit the amount of correction seen with this maneuver.

**Forefoot valgus**
The foot with a structural forefoot valgus has an everted orientation of the forefoot in relation to the rearfoot when placed in the nonweight-bearing STJN position. A typical compensation for this foot deformity may be abnormal supination during midstance. As with the forefoot varus deformity, when the medial calcaneal condyle has reached the ground in midstance, the foot is not plantigrade. However, with this foot deformity the lateral border of the foot is elevated from the ground surface. To get the lateral border of the foot on the ground, the STJ (if pain and motion allow) supinates (see Fig. 13B and D). This supination occurs at a time in the gait cycle when the foot should be pronating, and is characterized by inversion of the calcaneus, adduction of the forefoot, and an increase in the height of the medial longitudinal arch. This abnormal compensation can be seen when a total forefoot valgus deformity is present, or with a rigid planatarflexed first ray. If a planatarflexed first ray is present, it is important to assess its mobility, because the ability or inability of the first ray to dorsiflex can greatly affect the way the foot functions in weight bearing. If the plantarflexed first ray is mobile, meaning that the first ray can be easily dorsiflexed to the level of the other metatarsal heads, this most likely has little effect on overall foot position in weight bearing. If first ray mobility is limited, that is, it cannot be dorsiflexed to the level of the other metatarsal heads, the
weight-bearing foot functions differently from the foot with a mobile plantarflexed first ray. If, on the other hand, the plantarflexed first ray is rigid, assessment of rearfoot mobility is also necessary. If the hindfoot is flexible and the forefoot valgus deformity fixed, then correction of the forefoot secondarily causes correction of the rearfoot. If the hindfoot is not flexible, then correction of the forefoot cannot produce rearfoot correction. The Coleman block test is
a simple test to help determine the driving force behind the rearfoot position. To perform the test, the lateral border of the forefoot is placed on a block, varying from 0.5 to 2.5 cm, and the medial forefoot allowed to settle to the floor. If the rearfoot corrects with this test, then treatment should address only the forefoot. If the rearfoot does not correct, then treatment needs to address a combination of the forefoot and rearfoot. Similarly, use of lateral forefoot wedging can be used to assess the role the forefoot plays in the position of the rearfoot when a total forefoot valgus deformity is present.

**Forefoot equinus**

Forefoot equinus is a position of plantarflexion of the forefoot compared with the rearfoot. If adequate dorsiflexion ROM is available at the ankle joint, no other compensation is required for this forefoot deformity. If ankle joint dorsiflexion is insufficient, compensation has to occur through the oblique axis of the midtarsal joint, because that is the only other source of dorsiflexion ROM in the foot and ankle complex. For this to occur, the STJ must be pronated to allow the needed mobility of the midtarsal joint. As with other abnormal compensations, this inappropriate timing and/or range of pronation may cause difficulty with pain and/or gait abnormalities.

**Developmental trends**

It is essential that those of us who deal with the pediatric patient appreciate normal and abnormal developmental parameters for the various stages of growth. In general, a newborn shows increased varus positioning of both the forefoot and rearfoot, metatarsus adductus, and excessive ROM in the subtalar and ankle joints. There is little clinical evidence of a medial longitudinal arch until age 4 to 5 years. By 7 to 8 years of age, the child’s foot should have developed the adult values of 0 to 2° of rearfoot and forefoot varus, 5 to 15° of metatarsus adductus, and significantly less ROM through the ankle and STJs. Clinical evaluation of the foot must be directly related to the child’s age to determine if the deformity or problem is significant or not.

**Leg Length**

Good assessment of limb length inequality can by complicated by scoliosis, hip subluxation, pelvic obliquity, unilateral contracture of the hip adductors or abductors, or knee flexion contracture. In the absence of an asymmetric hip or knee contractures, limb length can be measured clinically in supine using the inferior border of the ASIS and the distal aspect of the medial malleolus, or standing using blocks to equalize the ASIS or the iliac crest height. Radiographic assessment is necessary if too many compounding factors are present.

**POSTURE AND BALANCE**

Assessment of posterior, anterior, and mediolateral equilibrium responses should not be neglected when planning treatment. Many children with CP have delayed or deficient posterior equilibrium responses. Assessment of posture, including trunk, pelvis, and lower extremity posture in static standing and during walking in the sagittal and coronal planes often gives insight to areas of weakness, poor motor control, and the compensation strategies that the child is using to circumvent them.

**GAIT BY OBSERVATION**

Observational gait analysis consists of observing a patient without the use of formal gait analysis equipment. Experience and use of a systematic method can improve the ability to identify primary and compensatory gait deviations. Various forms and scales have been developed to assist the observer in organizing the analysis as well as for reporting the observations. The Observational Gait Scale, and the Edinburgh Visual Gait Score are validated scales for outcome measurement but may not fully describe what the clinician is seeing. Krebs and colleagues reported that observational gait analysis is more consistent with a single observer. They further observed that viewing a video of a patient walking is more consistent than viewing the patient live with repeated walks. Finally, if slow motion video is used, these investigators found that the consistency of observation improved markedly.

Beginning with the feet, here are several questions to consider while observing gait:

1. What is the position of the foot at the end of terminal swing? Is the foot neutral or is it in a varus or valgus position?
2. Is the ankle in a neutral position or equinus?
3. Which portion of the foot contacts the floor first?
4. What is the foot progression angle during stance and swing with respect to both the line of progression and the alignment of the knee?
5. Is the foot plantigrade in stance?
6. Does the forefoot maintain its alignment with the hindfoot, and is the arch maintained?
7. At which point in the cycle does any deviation in the foot occur?
8. Does the foot go through the normal sequence of rockers, or is there premature plantarflexion in midstance, or prolonged dorsiflexion in terminal stance?
9. What are the positions of the toes in stance and swing? Is there toe clawing that is occurring in stance, or hyperextension of the first metatarsophalangeal joint in swing?

At the knee the following should be noted:

1. What are the positions of the knee in terminal swing and at initial contact?
2. Is the normal loading response (slight flexion followed by extension in early stance as the limb is loaded) present?
3. Does the knee come to full extension at any point in stance? If so, when?
4. Does the knee hyperextend, or is the extension controlled?
5. What is the maximum knee flexion in swing? When does it occur?
6. Is the knee aligned with the foot?
7. Is the shank aligned with the thigh?
8. Is there a varus or valgus motion during loading?

Gait by observation is more difficult proximally. The mass of the trunk, and the soft tissue around the hips and pelvis frequently obscure these joint motions. Because selective motor control tends to be better in the proximal and worse in the distal muscles, compensatory motions for distal gait problems often occur proximally via hip or trunk motion. However, without computerized gait analysis, it is difficult to determine whether the abnormal movements are compensations, or primary deviations. When observing the trunk, pelvis, and hips, note:

1. Is the thigh (knee) aligned to the line of progression at initial contact? If not is the malrotation internal or external?
2. Does the hip extend fully in terminal stance?
3. Is hip abduction (circumduction) or adduction (scissoring) excessive in swing?
4. Is pelvic position normal or is it excessively anterior or posterior?
5. Is pelvic malrotation or obliquity present?
6. What are the trunk movements in each plane? Are these appropriate?
7. Are the abnormal motions likely to be primary or compensatory?
8. How are the arms moving during gait? Are they moving symmetrically and reciprocally or are they postured?
9. Does the child elevate his/her arms to assist with balance?

And finally, some general questions to be considered in a gait-by-observation analysis:

1. Is the stride length adequate and are the step lengths symmetric?
2. Does the walking pattern seem to be efficient or is there excessive body motion or other indications of excessive energy consumption?
3. What influence do assistive devices or orthotics have on the child’s walking pattern?

REFERENCES