J Orthop Spine Trauma. 2023 June; 9(2): 88-92. DOI: 10.18502/jost.v9i2.12827

Educational Corner

Approach to Lower Limb Disabilities in Cerebral Palsy: An Educational Corner

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Received: 14 December 2022; **Revised:** 27 February 2023; **Accepted:** 12 April 2023

Keywords: Cerebral Palsy; Spastic Diplegia; Little Disease; Lower Limb

Citation: Shirbache K, Nabian MH, Anaraki N, Mehrpour SR. **Approach to Lower Limb Disabilities in Cerebral Palsy: An Educational Corner.** *J Orthop Spine Trauma* 2023; 9(2): 88-92.

Definition and Classification

Cerebral palsy (CP) is a group of movement disorders that affect a person's posture, balance, and gait. This clinical manifestation is caused by permanent and non-progressive damage to the brain. In this article, in order to promote the best orthopedic care to this group of patients, we will present the orthopedic approach to lower limb disabilities in CP patients step by step (1).

Based on clinical features and prominent neurological findings, CP patients are divided into 3 main groups after the topographical classification: spastic, dyskinetic, and ataxic. The Gross Motor Function Classification System (GMFCS) and Functional Mobility Scale (FMS) classification are explained in the related sections (1).

History

As an orthopedic specialist, it is very important to know whether you are seeing a patient with a diagnosis of CP or not. When you see a new patient, you should consider other possible differential diagnoses and pay close attention to co-morbidities. Diagnosing CP requires an extensive interview, analysis of the child's development, multiple tests, and CNS imaging. Therefore, it may be necessary to refer the patient to a pediatric neurologist for further evaluations. To be aware of the authenticity of the primary diagnosis of CP, it is helpful to pay attention to some points in the patient's history (2). Consider the red flags in CP history taking mentioned in table 1.

Table 1. Red flags in Cerebral palsy (CP) history

Red flags		
History	**Clinical exam**	**Paraclinical**
Similar disease in the family	Dysmorphic facies	Normal brain MRI
Parental relatedness	Neurocutaneous lesions	Isolated abnormal globus pallidus signals
No risk factors	Systemic signs	Incompatible imaging findings with CP symptoms
No sentinel events	Retinopathy or optic atrophy	Cerebellar atrophy
Stoppage or regression in neurodevelopment	Isolated muscular hypotonia	Demyelination
Fluctuation in motor functions	Paraparesis	
Episodic deterioration		

Nevertheless, if the patient is a known case of CP, we should only focus on musculoskeletal problems and their related complications. The history of the child's developmental milestones is very helpful in making subsequent decisions. Having a good knowledge of the child's developmental process and his/her current level of functional activity, it is possible to predict the natural history of the patient and set goals for follow-up and treatment (2).

Functional Mobility Scale

A person's performance at home, school, and in the community, as well as skills such as walking, running, and climbing stairs, should also be carefully questioned. The FMS evaluates the motor efficiency of CP children based on disabilities and compensatory reactions, which includes different classifications. The classification of FMS is presented in the table 2 (3).

Table 2. Functional Mobility Scoring

	Grade	Walking distance	Score		Description
1	Home	5 m	Score for each Grade	1	Mostly use wheelchair/ able to stand for transfer/ Some stepping with caretaker or walker support
				2	Using a walker or frame for walking
2	School	50 m		3	Walking independently with a crutch support
				4	Walking independently with stick (one or two)
				5	Walking independently but on level surfaces
3	Community	500 m		6	Walking independently on all surfaces
				C	Crawling for mobility
				N	Not applicable for 500 m distances

Clinical Exam

CP patients' examination consists of the two dimensions of static and dynamic. Here we explain both parts practically. First, examine each limb anatomically.

Hip examination in CP is important because late dislocation may occur in this joint following abnormal muscular balance, loss of selective motor control, and muscle tone abnormalities. Therefore, screening children, especially non-walkers and late walkers, is very important (4). In the knee, the first step in dealing with a flexion contracture of the joint is to differentiate the real contracture from spasticity or muscle stiffness. In the ankle and foot examination, concentration should mostly be on checking for equinovarus and planovalgus, which are the most common manifestations in CP (4).

Lever arm dysfunction should be investigated in all children with CP because it describes a group of the most common disorders that lead to insidious complications such as hip subluxation, torsional deformities of long bones, and/or foot deformities. Body locomotion consists of muscles and ground reaction forces (GRFs); however,

these factors are not efficient in CPs because of bone modeling, reconstruction, or traumatic abnormalities that render the child unable to walk. Excessive femoral anteversion (FAV), tibial torsion, and coxa valga are categorized as lever arm dysfunction and result in in-toeing gait and hip instability (5).

The most practical examinations for each section are provided in table 3 (4-6).

Table 3. Clinical examination tests

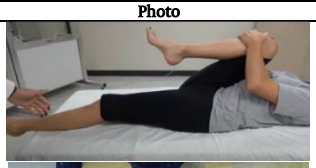
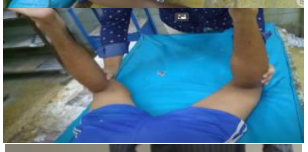
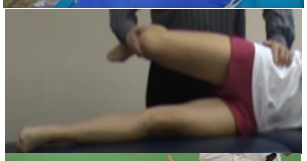
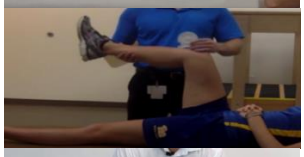
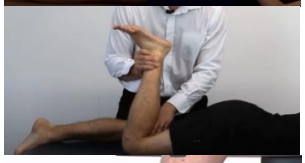
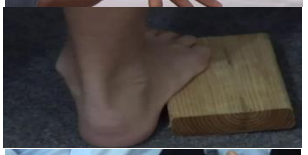
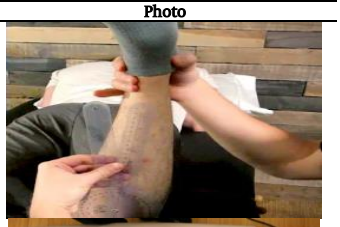
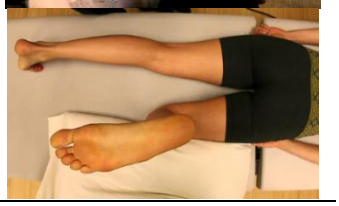
	Section	Test	Description	Photo
1	Hip	Thomas' hip flexion test	The flexion contracture of the hip is determined in supine position. Hip flexion contracture is defined based on the angle between the horizontal axis of the thigh and the floor line.	
		Staheli test	Hip flexion contracture is evaluated in prone position. The angle between the long axis of the thigh and the floor line indicates the flexion contraction.	
		Phelps test	The amount of adductor contracture and passive abduction is evaluated in supine position, and the future risk of hip subluxation and chronic hip pain is determined.	
		Ober's test	The tensor fasciae latae (TFL) and iliotibial band (ITB) are checked in lateral position; if the patient reports lateral knee pain, the test is positive and ITB involvement is considered.	
2	Knee	Joint contracture test	With the hip joint in extension and the ankle in plantar flexion, the true knee contracture is determined in supine position.	
		Popliteal angle test	Hip flexion contracture is distinguished from anterior pelvic tilt and length of hamstrings is evaluated unilaterally and bilaterally in the supine position.	
		Duncan-Ely/Prone Rectus test	The rectus femoris, associated with hamstring contracture, is examined in prone position	
3	Ankle	Confusion test	To check dorsiflexion, the hip joint is flexed against resistance, in order to check selectivity in muscles.	
		Coleman Block Test	The presence of fixed or flexible deformity is determined in cavovarus foot; if the heel deformity is corrected while weight bearing during this test, it is flexible, and if not, it is a rigid deformity.	
		Silfverskiold test	The ankle is dorsiflexed passively in both the knee extension and the knee flexion at 90 degrees, a difference of 20-30 degrees in these two positions indicates a gastrocnemius contracture.	 

Table 3. Clinical examination tests (continue)

	Section	Test	Description	Photo
4	Lever arm dysfunction	Craig's test (Netter maneuver)	FAV is determined in prone position and with both knees in 90 degrees of flexion; the angle between the vertical line and the long axis of the leg at the greatest prominence of the greater trochanter determines the FAV value.	
		Thigh-foot angle test	To assess tibial torsion, the knees are flexed 90 degrees in prone position, and the angle between the thigh and the foot are determined.	

Gait Analysis

Instrumented gait analysis is very useful in the evaluation of gait deviations and can help to determine the most appropriate intervention for the patient; however, to offer something useful for all examiners in daily clinics without any equipment, we introduce observational gait analysis based on topographical aspects of CP. In this technique, we ask the child to walk in a private room several times and evaluate him/her in sagittal and coronal planes. The range of motion (ROM) of the gait cycle and joint should be observed carefully at different time frames (5).

Gross Motor Function Classification System

In order to evaluate the overall function of the lower body and choose the best therapeutic intervention for each child, the use of GMFCS is very helpful. The placement of the child in each subgroup (1-5) is based on his/her type of assistive device (wheelchair, cane, walker, crutch, etc.) and quality of performing daily activities (Table 4) (4).

Table 4. Gross Motor Function Classification System

Level	Description
I	The child can walk, run and jump freely, but with decreased speed, balance and coordination.
II	The child can walk freely, but climb stairs, run, and jump with mild limitations.
III	The child can walk only with auxiliary equipment. Climbing stairs is possible only with railings, and propelling a manual wheelchair only for short distances.
IV	The child cannot walk easily even with auxiliary equipment and there are certain limitations; using an electric wheelchair is a must for indoor transfer.
V	The child cannot move, sit, or stand on his/her own; there is poor control of movements. Help of an assistant is necessary for all activities.

Axial Skeleton

Scoliosis, kyphosis, lordosis, pelvic obliquity, or a combination of these can be expected in CP patients. Scoliosis is very common in patients with GMFCS IV-V. Scoliosis starting at a young age (< 15 years) has a poorer prognosis. Usually, the onset of puberty, loss of neurologic function, or long-term use of a wheelchair accelerates the development of deformity. It is important to pay attention to the changes and complications caused by spinal deformities in periodical examinations (5).

Joint Range of Motion

ROM also indirectly indicates muscle length and gives a good estimate of joint contracture, so measuring this parameter with a manual goniometer could be very valuable in CP's clinical exam both statically and dynamically (4).

Balance

Finally, in order to evaluate the child's motor control and the compensatory mechanisms of the body, it is necessary to carry out a detailed analysis of the patient's balance at all levels by examining the trunk position, body balance, and pelvis and lower limb position while sitting, standing, and walking (4).

Imaging

Simple X-ray is the best option for initial examination, and more specialized imaging is chosen according to it. In this section, we discuss the imaging and practical views of each part (7).

Hip

Since hip abnormalities are very common in CP patients, AP pelvic view is recommended to evaluate hip displacement and dislocation. In order to determine the migration percentage, the Hilgenreiner line, and Perkin's line and its parallel lines should be drawn according to the following rules (7).

First, the Hilgenreiner line is drawn horizontally on the upper part of the hip cartilage. In mature children, the inferior points of the acetabular teardrops are used. Then, Perkin's line is drawn perpendicular to the Hilgenreiner line in the lateral part of the edge of the acetabulum. After that, two lines parallel to Perkin's line are drawn on the inner and outer edge of the femoral head. The width of the femoral head (ab) and the distance between Perkin's line and the outer edge of the femoral head (ac) are measured and the hip migration percentage is calculated based on the formula: ac/ab × 100%. Usually, a migration percentage of more than 30% in CP children is considered pathological (7) (Figure 1/A).

Knee

To evaluate knee deformities, three views are used as follows:

AP View: AP view is a standard view for general evaluation of the knee joint (7).

Sunrise View: This view is used in suspected cases of subluxation or dislocation of patella or patellar maltracking (7).

Maximum extension lateral knee view is used to measure the amount of contracture in cases of crouch gait or knee flexion contractures (7) (Figure 1/B).

30° lateral view: This view is used in suspected cases of inferior patellar pole fractures or superior displacement of the patella within the trochlear groove of the femur, which is called patella alta (7).

There are several criteria for the evaluation of the patella alta, here we will explain the Insall-Salvati Index. This index measures the ratio of the length of the patellar tendon to the length of the patella by considering the

length of the patellar tendon from the inferior pole of the patella to the tibial tubercle and measuring the length of the patellar from the superior pole to the inferior pole. Then, the length of the patellar tendon is divided by the length of the patella. The normal range of this index is 0.74-1.5. If ISI is more than 1.5, it is considered patella alta (8) (Figure 1/C).

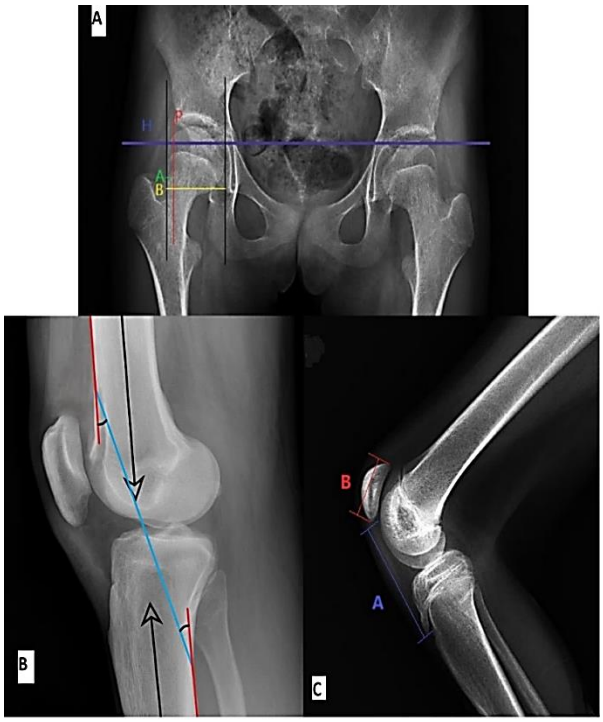


Figure 1. A: Hilgenreiner line and Perkin's line; B: Maximum extension lateral knee; C: line Insall-Salvati Index

Ankle

AP View: One of the most important indices in ankle AP view is the tibiocalcaneal angle, the normal range of which is 69˚ ˚± 8.4˚˚, its higher values are found in equinus and other plantarflexion deformities (Figure 2/A).

The calcaneal pitch index has a function similar to the tibiocalcaneal angle with a normal range of 39˚ ± 7˚ (7) (Figure 2/B).

Lateral View: In this view, the lateral talocalcaneal angle is evaluated to check hindfoot deviations; its normal range is 49˚ ± 6.9˚˚, an angle greater than this indicates valgus hindfoot and less than this indicates varus hindfoot. The lateral talus-first metatarsal angle is used to evaluate the midfoot. The normal range of this index is 13˚ ± 7.5˚ (7) (Figure 2/C).

Weight-bearing AP View: In this view, the talocalcaneal angle with a range of 10˚-56˚ is used to check the hindfoot alignment (Figure 2/D). The normal range of talonavicular coverage angle is 20˚ ˚± 9.8˚ (7) (Figure 2/E). The talo-first metatarsal angle with a range of 10˚ ± 7˚ is considered to evaluate the forefoot alignment (Figure 2/F). There are some other additional views used for malalignments in CP patients. Teleogram is a view that shows all three joints of the hip, knee, and ankle on both sides in one film, and it is used in cases of leg length inequality (8).

MRI and CT scan are used for more detailed examination of joints and bones in case of suspected osteomyelitis, bone necrosis, and tumors that may be found in simple X-ray or examination of children with CP (7, 8).

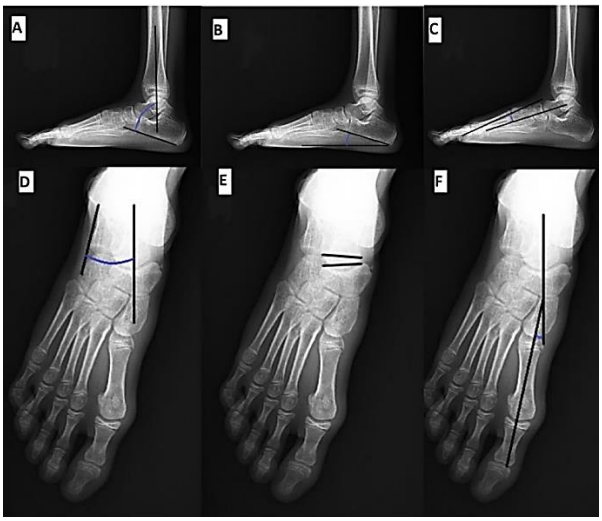


Figure 2. A: Tibiocalcaneal angle; B: Calcaneal pitch; C: Lateral talus-first metatarsal angle; D: Talocalcaneal angle; E: Talonavicular coverage angle; F: Talo-first metatarsal angle

CP Complications

There are three categories of impairments in CP patients. Primary impairments include derivational disabilities caused by CNS damage, such as complications including abnormal muscle tone and strength, lack of balance, and selectivity disorder which exist in patients from birth. Orthopedic interventions in this field are very limited and often include medication. However, in the case of secondary impairments, orthopedic surgery can play a helpful role. These disorders appear over time and in response to initial problems. As the muscles grow, the initial complications prevent their natural stretching, and eventually, debilitating contractures occur, which are more in distal biarticular muscles than monoarticular muscles. In this category of disorders, bone deformity is also included, which is caused by contracture, weakness, and spasticity of muscles. Finally, the child with CP achieves adaptive mechanisms over time to adapt to primary and secondary disorders, which causes tertiary impairments, such as hyperextension of the involved joints, which occurs following primary spasticity and secondary contracture for maximum use of the limb (9, 10).

Conclusion

When seeing CP patients, the ultimate goal is to evaluate patients completely in order to provide a better service to them which minimizes the disability and improves their independence in order to participate in society more conveniently. Since orthopedic surgeries play a small role in primary and tertiary complications, it is necessary to distinguish the types of motor impairment in these patients. The importance of history, examination, and paraclinic in the approach to the CP patient is in the determination of secondary complications and their discrimination from the others, so that the patient's treatment plan can be selected more precisely.

Conflict of Interest

The authors declare no conflict of interest in this study.

Acknowledgements

None.

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