



# NCC Pediatrics Continuity Clinic Curriculum: Lower Limb Deformities

## Goals & Objectives:

- Describe normal development of the lower limb.
- Describe how to evaluate torsional and angular deformities of the lower limb and differentiate physiologic from pathologic deformities.
- Describe possible interventions for common deformities such as DDH, femoral anteversion, tibial torsion, clubfoot, metatarsus adductus, and pes planus.

## Pre-Meeting Preparation:

*Please read the following enclosures:*

- Excerpts from “Torsional and Angular Deformities” (*Nelson’s Pediatrics*)
- “Common Lower Extremity Problems in Children” (*PIR 2004*)
  - *Can skim LCP and SCFE sections—will not discuss in this module*
- Excerpts from AAP CPG for DDH (*Pediatrics, 2000*)

## Conference Agenda:

- Review Lower Limb Deformities Quiz
- Complete Lower Limb Deformities Cases
- **Hands-on Exercise: Pair up & perform a rotational profile on your partner (or on one of your preceptors). Fill out the worksheet.**

Post-Conference: Board Review Q&A

## Extra-Credit:

- Wells, L. and Sehgal, K. (2011). [Torsional and Angular Deformities](#). In Kliegman (19<sup>th</sup> Ed) **Nelson Textbook** of Pediatrics (pp. 2344-2350). Philadelphia: Elsevier.
- Deeney, V.F et al. (2012). [Orthopedics: Disorders of the Lower Extremity](#). In **Zitelli** and Davis (6<sup>th</sup> Ed) Atlas of Pediatric Physical Diagnosis (848-862). Philadelphia: Elsevier.
- [Complete Report on AAP Clinical Practice Guidelines: Early Detection of Developmental Dysplasia of the Hip](#) (2000)
- [“Lower Extremity Disorder in Children and Adolescents”](#) (*PIR, 2009*)

## Chapter 667 – Torsional and Angular Deformities

### 667.1 Normal Limb Development

Lawrence Wells,  
Kriti Sehgal

An understanding of normal limb development is essential for pediatricians to recognize pathologic conditions during routine and targeted exams. During the 7th wk of intrauterine life, the lower limb rotates medially to bring the great toe toward the midline. The hip joint forms by the 11th wk; the proximal femur and acetabulum continue to develop until physeal closure in adolescence. At birth, the femoral neck is rotated forward approximately 40 degrees. This forward rotation is referred to as anteversion (the angle between the axis of the femoral neck and the transcondylar axis). The increased anteversion increases the internal rotation of the hip. Femoral anteversion decreases to 15-20 degrees by 8-10 yr of age. The second source of limb rotation is found in the tibia. Infants can have 30 degrees of medial rotation of the tibia, and by maturity the rotation is between 5 degrees of medial rotation and 15 degrees of lateral rotation (Fig. 667-1). Excessive medial rotation of tibia is referred to as *medial tibial torsion*. The tibial torsion is the angular difference between the axis of the knee and the transmalleolar axis. The medial or lateral rotation beyond  $\pm 2$  standard deviations (SDs) from the mean is considered abnormal rotation.

Limb rotation is also found in the foot. The abnormalities could be excessive adduction or abduction. Torsional deformity may be simple, involving a single segment, or complex, involving multiple segments. Complex deformities may be additive (internal tibial torsion and internal femoral torsion are additive) or compensatory (external tibial torsion and internal femoral torsion are compensatory).

The normal tibiofemoral angle at birth is 10-15 degrees of physiologic varus. The alignment changes to 0 degrees by 18 mo, and physiologic valgus up to 12 degrees is reached in between 3 and 4 yr of age. The normal valgus of 7 degrees is achieved by 5-8 yr of age (Fig. 667-2). Persistence of varus beyond 2 yr of age may be pathologic. Overall, 95% of developmental physiologic genu varum and genu valgum cases resolve with growth. Persistent genu valgum or valgus into adolescence is considered pathologic and deserves further evaluation.

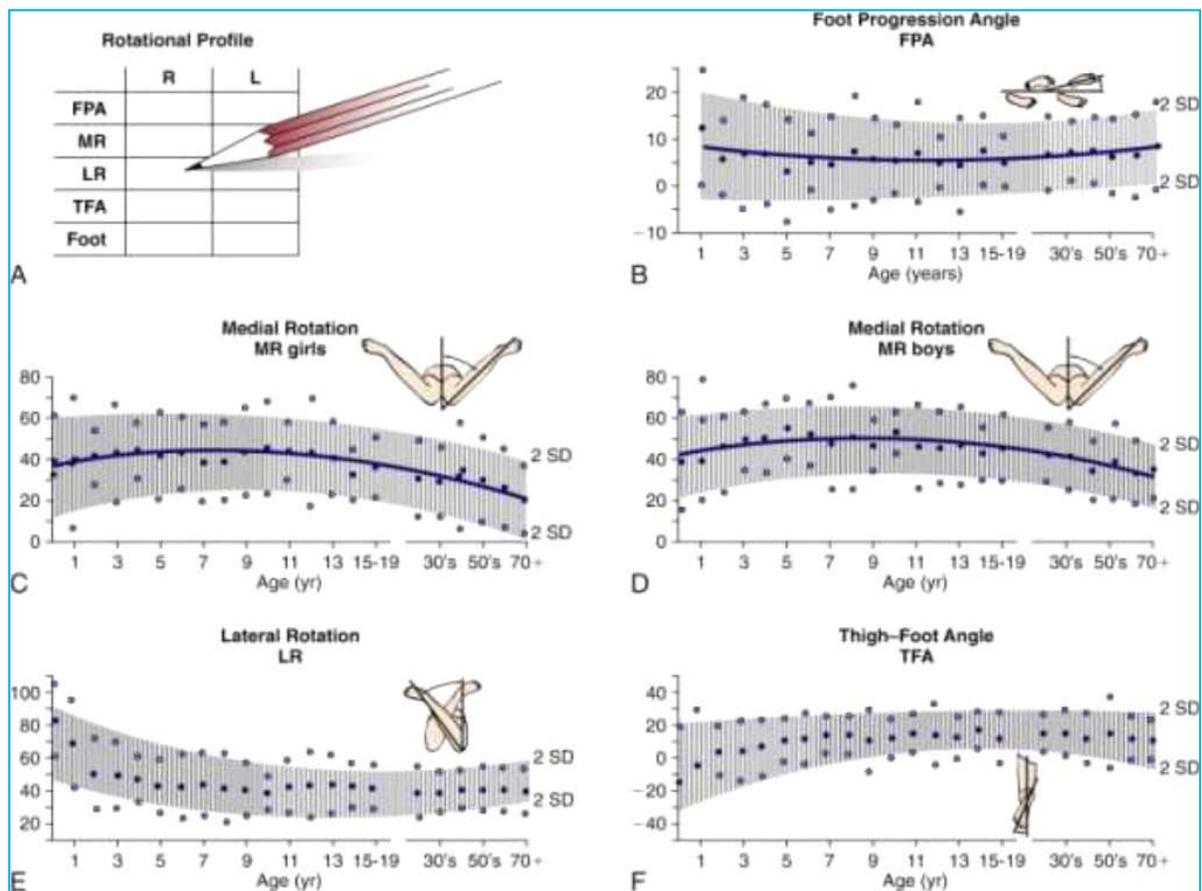


Figure 667-1 A-F, The rotational profile from birth to maturity is depicted graphically. All graphs include 2 standard deviations from the mean for: the foot progression angle (FPA) for femoral medial rotation (MR) and lateral rotation (LR) (for boys and girls), and the thigh-foot angle (TFA). (From Morrissey RT, Weinstein SL, editors: *Lovell and Winter's pediatric orthopaedics*, ed 3, Philadelphia, 1990, Lippincott Williams & Wilkins.)

## 667.2 Evaluation

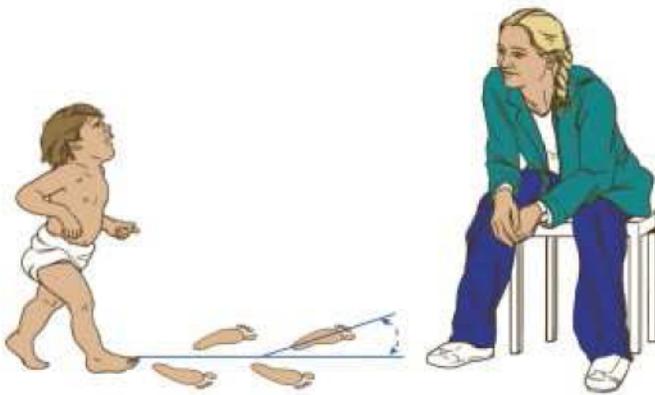
Lawrence Wells,  
Kriti Sehgal

In evaluation of concerns relating to the limb, the pediatrician should obtain a history of the onset, progression, functional limitations, previous treatment, evidence of neuromuscular disorder, and any significant family history.

The examination should assess the exact torsional profile and include (1) foot progression angle, (2) femoral anteversion, (3) tibial version with thigh-foot angle, and (4) assessment of foot adduction and abduction.

### Foot Progression Angle

Limb position during gait is expressed as the foot progression angle (FPA) and represents the angular difference between the axis of the foot with the direction in which the child is walking. Its value is usually estimated by asking the child to walk in the clinic hallway (Fig. 667-3). Inward rotation of the foot is assigned a negative value, and outward rotation is designated with positive value. The normal FPA in children and adolescents is 10 degrees (range, -3 to 20 degrees). The FPA serves only to define whether there is an in-toeing or out-toeing gait.



**Figure 667-3** Foot progression angle. The long axis of the foot is compared with the direction in which the child is walking. If the long axis of the foot is directed outward, the angle is positive. If the foot is directed inward, the angle is negative and indicates in-toeing.

(From Thompson GH: *Gait disturbances*. In Kliegman RM, editor: *Practical strategies in pediatric diagnosis and therapy*. Philadelphia, 2004, Saunders.)

### Femoral Anteversion

Measuring the hip rotation with the child in prone position, the hip in neutral flexion or extension, thighs together, and the knees flexed 90 degrees indirectly assesses the anteversion (Fig. 667-4). Both hips are assessed at the same time. As the lower leg is rotated ipsilaterally, this produces internal rotation of the hip, whereas contralateral rotation produces external rotation. Excessive anteversion increases internal rotation, and retroversion increases the external rotation.



## Tibial Rotation

Tibial rotation is measured using the transmalleolar angle (TMA). The TMA is the angle between the longitudinal axis of the thigh with a line perpendicular to the axis of the medial and lateral malleolus (Fig. 667-5). In the absence of foot deformity, the thigh foot angle (TFA) is preferred (Fig. 667-6). It is measured with the child lying prone. The angle is formed between the longitudinal axis of the thigh and the longitudinal axis of the foot. It measures the tibial and hindfoot rotational status. Inward rotation is assigned a negative value, and outward rotation is designated a positive value. Inward rotation indicates internal tibial torsion, whereas outward rotation represents external tibial torsion. Infants have a mean angle of  $-5$  degrees (range,  $-35$  to  $40$  degrees) as a consequence of normal in utero position. In mid-childhood through adult life, the mean TFA is  $10$  degrees (range,  $-5$  to  $30$  degrees).

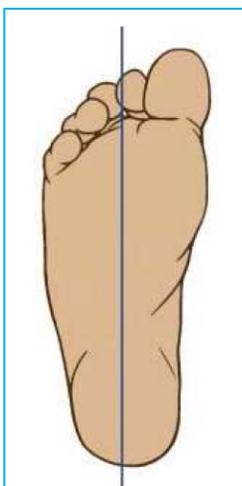
**Figure 667-5** The transmalleolar angle is measured with the patient sitting at the edge of the table and the distal femoral condyles aligned with the side of the table. The angle between a line through the medial and lateral malleoli and edge of the table should be approximately 30 degrees external.



**Figure 667-6** Thigh-foot angle.

## Foot Shape and Position

The foot is observed for any deformities in prone and standing position. The heel bisector line (HBL) is used to evaluate the foot adduction and abduction deformities. The HBL is a line that divides the heel in two equal halves along the longitudinal axis (Fig. 667-7). It normally extends to the 2nd toe. When the HBL points medial to the 2nd toe, the forefoot is abducted, and when the HBL is lateral to the 2nd toe, the forefoot is adducted.



**Figure 667-7** Schematic demonstration of heel bisector line.

# Common Lower Extremity Problems in Children

Susan A. Scherl, MD\*

**Objectives** After completing this article, readers should be able to:

1. Describe the presentation of hip joint pathology in children.
2. Know how to treat most rotational and angular deformities.
3. Describe the hallmark of clubfoot that helps to differentiate it from isolated metatarsus adductus.
4. Explain why screening for developmental dysplasia of the hip should be performed.
5. Describe foot problems that can be markers for a neurologic disorder.

## Overview

Growing children are susceptible to a variety of developmental lower extremity disorders of varying degrees of seriousness. Because children are growing and developing and are not simply smaller versions of adults, it can be difficult to treat some conditions, but in other cases, there is leeway in the results of treatment not available to adults. Long-term outcome is of utmost importance for pediatric patients because their bones, joints, and muscles optimally should remain functional and pain-free during childhood and throughout their lives. Treatment should disrupt daily life as little as possible to minimize the social and psychological toll of the illness.

Common lower extremity problems in children can be grouped broadly into four categories: rotational deformities, angular deformities, foot deformities, and hip disorders. This article covers the major conditions in each group. Pediatricians and other primary care clinicians can expect to encounter these disorders in their practices. A working knowledge of the basics of these disorders will help in appropriate diagnosis, treatment, counseling, and referral of patients.

## Rotational Deformities

The developmental rotational deformities, intoeing and outtoeing, probably are the most common childhood musculoskeletal entities that prompt parents to consult a physician. Because intoeing is more common than outtoeing, the chief complaint generally is that the child is “pigeon-toed” or that his or her “feet turn in” when he or she stands, walks, or runs. Often, the parents express concern that the pigeon-toeing is leading to falls, and they may volunteer that as children they themselves needed “braces” or “special shoes” for a similar problem. It may be helpful to begin the consultation by reassuring the family that most rotational deformities are variations of normal that correct spontaneously without the need for surgical intervention.

### Intoeing

Intoeing has three possible locations of origin: the foot, between the knee and the ankle, and between the hip and the knee. When the origin is the foot, the condition is known as metatarsus adductus, meaning that the forefoot (the tarsal and phalangeal bones) is angled toward the midline of the body. This sometimes is described as a “bean-shaped” foot. Metatarsus adductus is a “packaging defect,” meaning that it is a deformity believed to be a direct result of the positioning of the baby inside the womb. The classic “fetal position” predisposes to metatarsus adductus.

Clinically, the foot has a convexity along the lateral border and may have a transverse crease medially at the junction of the fore- and midfoot. The amount of adduction can be

\*Pediatric Orthopedics, The University of Nebraska, Omaha, NE.



**Figure 1.** Metatarsus adductus and heel bisectors. The foot on the left is normal; the foot on the right has moderate metatarsus adductus.

quantified grossly by extrapolation of a line bisecting the heel up to the forefoot. Normally, a heel bisector should hit between the second and third rays of the foot. Hitting the third ray is considered mild metatarsus adductus, hitting the fourth ray is moderate, and hitting the fifth is severe (Fig. 1). The heel bisector quantification can be used to follow the resolution of metatarsus adductus over time.

Metatarsus adductus also can be classified in terms of flexibility, which can be useful in determining the necessary treatment. Metatarsus adductus is considered actively correctable if the baby straightens the foot in response to being tickled along its lateral border. Passively correctable metatarsus adductus does not correct when the foot is tickled, but does correct with gentle laterally directed pressure on the first metatarsal head. Rigid metatarsus adductus does not correct, even with stretching.

No specific treatment is necessary for actively correctable metatarsus adductus; spontaneous correction is the rule. For passively correctable metatarsus adductus, stretching exercises, in which the deformity is corrected as described previously, are performed five times per foot, holding the correction for 10 seconds, with each diaper change. For rigid feet, either “stretch casting,” in which a series of casts is used to straighten out the deformity gradually, or the “Wheaton brace” (Fig. 2), a removable, plastic version of a stretch cast, are treatment options, although it is somewhat controversial whether such casts change the natural history of the disorder.

The differential diagnosis for metatarsus adductus is clubfoot. Clubfoot is a more complex foot disorder that



**Figure 2.** The Wheaton brace.

includes three separate deformities, of which metatarsus adductus is one. The hallmark of a clubfoot is equinus, the inability to dorsiflex at the ankle, which is not a feature of metatarsus adductus. It is important to differentiate between the two conditions because the treatments and prognoses are different. Finally, there is some mention in the literature of an association between metatarsus adductus and developmental dysplasia of the hip. Newer evidence does not support this hypothesis, but for medicolegal reasons, it is important to screen children who have metatarsus adductus for hip dysplasia.

When the point of origin of intoeing is between the knee and the ankle, the condition is known as tibial torsion, meaning a twist in the tibia bone. Like metatarsus adductus, tibial torsion is a packaging defect and is the most common cause of intoeing in children younger than 3 years of age. It is present at birth, but usually is noticed by the parents when the child begins to stand or walk. Tibial torsion gradually improves with the first year of ambulation; treatment rarely is necessary.

Medial femoral torsion (MFT) (sometimes known as femoral anteversion) is a twist in the femur between the hip and the knee. It is the most common cause of intoeing in children older than 3 years of age. The orthopedic literature generally distinguishes between “femoral anteversion,” which is the normal alignment of the proximal femur vis-à-vis the distal femur, and “medial femoral torsion,” which is pathologic degrees of femoral anteversion. Babies are born with increased femoral anteversion relative to adults (40 degrees versus 10



Figure 3. The "W" sitting position.

degrees), and they are born with lateral external rotation contractures that mask that difference. The natal anteversion decreases steadily by about 1.5 degrees per year. In contrast, most children who have clinically evident MFT have version angles *increased* to about 60 degrees between the ages of 4 and 6 years.

Children who have MFT typically sit in what is known as the "W" position (Fig. 3). The ability to sit comfortably in a "W" position is associated with both MFT and ligamentous laxity, an autosomal dominant variant of normal that is not inherently pathologic, but contributes to several musculoskeletal disorders in children and adults. Animal and experimental models have shown that increased loading of the femur in torsion (as occurs while sitting in the W position) can cause increased femoral version. This is the reason that some orthopedists now consider MFT to be an acquired rotational deformity and not simply a manifestation or persistence of an inherited extreme of natal femoral anteversion.

Generally, MFT resolves without intervention. Some orthopedists recommend that the parents discourage sitting in the "W" position, although the importance of doing so is controversial. The deformity continues to correct very slowly, until the age of 8 to 10 years.

### Outtoeing

Outtoeing is far less common than intoeing, but it usually is a packaging defect. About 20% of fetuses are positioned with hips and knees flexed, ankles dorsiflexed, and legs and feet externally rotated rather than being in

the typical fetal position. This may lead to external tibial torsion and calcaneovalgus feet. These represent the positional opposites of internal tibial torsion and metatarsus adductus and, like their counterparts, improve with the first year of walking.

When a child presents with a chief complaint of intoeing, the physician determines the underlying cause by using a simple series of tests known as the "rotational profile." The rotational profile is not only diagnostic, but it also can be used to chart progress in subsequent visits. The child's age also provides a clue; various causes are common to different age groups. The first step in the rotational profile is to watch the child walk to determine the "foot progression angle," which is the direction in which the child's feet point when he or she walks. By convention, intoeing is negative and outtoeing is positive. Most adults have a foot progression angle of about +10 degrees. The rest of the tests are performed with the child lying prone. First, the examiner extrapolates the heel bisector to check for metatarsus adductus. Then he or she imagines a line down the center of the thigh. The angle this line forms with the heel bisector is called the "thigh-foot angle" (Fig. 4) and should measure between 0 and +10 degrees. A negative thigh-foot angle indicates tibial torsion. Finally, the degrees of internal and external rotation at the hip joint are measured. Young children have roughly equal rotation, about 45 degrees ( $\pm 20$  degrees) in both directions. An increase in internal rotation indicates femoral torsion. It is neither necessary nor helpful to obtain radiographs or other imaging studies to diagnose rotational deformities. The history and physical examination findings are sufficient for an accurate diagnosis.

Parents often ask about the use of bars, braces, or shoes to correct rotational deformities. Although these have been used in the past, they no longer are used widely for rotational deformities because there is no evidence that they are effective. Most rotational deformities correct spontaneously. Moreover, there is no evidence that the common rotational deformities lead to any problems in adulthood; even when persistent, they are primarily cosmetic. There are relatively few indications for surgical intervention in these cases; the osteotomies required, in which the bones are cut and rotated to a new position, are major procedures reserved for deformities that significantly affect function and do not correct spontaneously. Interestingly, there is some evidence that persistent intoeing is beneficial for performance in sports in which quick directional shifts are necessary, such as tennis, soccer, and basketball. Therefore, families can be reas-

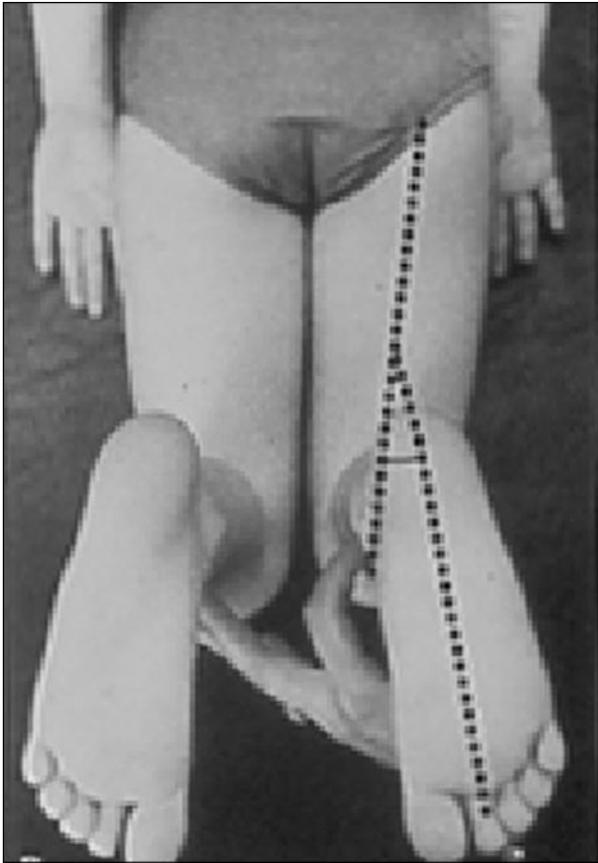


Figure 4. The thigh-foot angle.

sured that intoeing will not prevent their child from excelling in athletics.

A small number of children develop what has been termed “malignant malalignment syndrome.” Children who have malignant malalignment demonstrate increased medial femoral torsion combined with excessive lateral torsion of the tibia. This combination is cosmetically unappealing, and some children complain of anterior knee or patellofemoral pain due to the altered biomechanics of the leg axis and knee joint. If the knee pain cannot be managed with conservative treatment (physical therapy, activity modification, taping, and medication) or if the child has another underlying problem such as spastic diplegia, surgical treatment may be necessary. However, this surgery rarely is indicated and should not be undertaken lightly because it necessitates a significant operation involving a combination of both femoral and tibial osteotomy, usually bilaterally.

### Angular Deformities

The common lower extremity angular deformities in children are genu varum and genu valgum, colloquially



Figure 5. Measuring the distance between the ankles to follow progression of genu valgum.

known as bowlegs and knock-knees, respectively. Like the rotational deformities, these usually are “physiologic” or a variation of normal, and a typical progression has been described. All babies are born bowlegged, although parents usually notice this only when children start to pull up to stand. Between the ages of 2 and 3 years, the bowlegging gradually decreases, and by 3 years, the average child is maximally knock-kneed. The knock-kneeing straightens minimally over the next several years; by age 7 years, most children have reached the typical adult configuration, which is slightly knock-kneed. Thus, an explanation and reassurance of the parents often are the only interventions necessary. To follow the progression clinically, the clinician can measure every 6 months either the distance between the knees (with the ankles together) of children who have varus or between the ankles (with the knees together) of children who have valgus (Fig. 5). Persistent genu valgum is well tolerated functionally and tends to be more of a cosmetic concern, but genu varum that persists beyond the expected time frame can cause damage to the medial aspect of the knee joint and pain later in life.

An angular deformity is pathologic rather than physiologic if it is asymmetric, unilateral, or painful or if the trend of progression differs from the expected. The differential diagnosis includes isolated entities such as Blount disease, tumor and infection (both of which can damage a growth plate, resulting in angular deformity), and systemic conditions, such as rickets, renal disease, and various dysplasias (dwarfisms).

Blount disease is a condition of unknown cause in

which the medial proximal tibial physis becomes “sick” and does not function well, leading to undergrowth of the medial side of the tibia, which results in curving of the tibia. The infantile form of the disease was classified initially by Langenskiöld; the classification takes into account both the age of the patient and the degree of deformity. The classification starts at the age of 2 years; genu varum in children younger than 2 years almost always is considered physiologic, regardless of appearance. The disease is particularly common in African-Americans, girls, children who are large for their age, and children who were “early walkers” (ie, before 11 mo). Although bracing may be tried in children younger than age 4 years, the current treatment for infantile Blount disease generally is surgical, using an osteotomy to realign the tibia and restore the proper mechanical axis of the leg. Initial surgery usually is undertaken between the ages of 3 and 4 years, and the deformity is somewhat overcorrected in an effort to prevent recurrence of the deformity as the child continues to grow.

In the initial evaluation of a child who has an angular deformity, knowledge of the normal progression combined with some simple data from the history and physical examination help in making the diagnosis. Pathologic conditions, especially tumor and infection, are more likely to be painful, unilateral, or greatly asymmetric. Children who have Blount disease tend to be early walkers; those who have rickets, renal disease, and dysplasias frequently are late walkers. Children who have Blount disease usually are in the upper growth percentiles; the metabolic and genetic conditions associated with angular deformity tend to occur in children who are small for their age. Additionally, patients who have systemic disorders often exhibit other obvious manifestations of their conditions on physical examination.

Radiographs should be obtained if the deformity is unilateral, very asymmetric, or painful or if the overall trend is unexpected. Most pathologic conditions causing angular deformities have characteristic radiologic appearances that can help in making the diagnosis. Treatment of pathologic angular deformities varies by diagnosis, but usually is designed to address the underlying condition, with surgical correction undertaken if necessary.

## Foot Deformities

### Clubfoot (Talipes Equinovarus)

Clubfoot is a relatively common congenital deformity that occurs in 1:1,000 live births, with about 50% of the cases being bilateral. The male-to-female ratio for affected children is 2.5:1. Inheritance is multifactorial rather than mendelian, but increased risk appears to run

in families in which one member already is affected. Clubfoot also can be a component of a dysmorphic syndrome or neuromuscular disorder.

The clubfoot deformity consists of three separate components: metatarsus adductus, equinus, and hind-foot varus (supination). However, unlike isolated metatarsus adductus, clubfoot is not a packaging defect. There is some controversy about the cause of clubfoot, but it probably results from a primary germ-plasm defect or from an early intrauterine vascular event. Not only are the tarsal bones misshapen and misaligned in an affected foot, but they are reduced in size, as is the musculature in the posterior compartment of the leg. Therefore, for the child who has unilateral involvement, it is important to explain to the parents that the affected foot and calf always will be smaller than that of the unaffected side.

Clubfoot sometimes can be diagnosed by prenatal ultrasonography, although there tends to be a high false-positive rate, and results are operator-dependent. As this technique becomes more prevalent, the role for prenatal counseling and reassurance for parents who have a potentially affected child may increase.

There is an association between clubfoot and developmental dysplasia of the hip. Therefore, a child who has an obvious clubfoot must be screened very carefully for hip dysplasia with both serial physical examinations and imaging studies if the examiner deems them necessary.

Treatment consists of manipulation of the foot (usually with serially applied casts), surgery, or a combination of the two. Generally, casting is attempted for 3 months, and if unsuccessful, surgery is planned. Traditionally, the success rate for casting alone has been approximately 25%, with the remainder of children ultimately requiring surgery. Currently, however, the treatment of clubfoot is relatively controversial. Several groups are reporting extremely high success rates with revised manipulation regimens, and interest in nonoperative management is increasing. This is partially in response to evidence that although operative treatment generally results in functionally “normal” feet, long-term surgical outcomes in older, active adults may not be as good as previously believed.

### Cavus Foot

A cavus foot is a high-arched foot that typically is an inherited variation of normal and requires no intervention. However, new-onset, unilateral, painful, or progressive arching may be indicative of a neurologic problem such as Friedrich ataxia, Charcot-Marie-Tooth disease, a tethered spinal cord, or an intraspinal lesion. In such cases, treatment of the underlying disorder often

helps to resolve the foot deformity, but bracing and surgery can be used to aid shoe-wear and ambulation in refractory cases.

### Calcaneovalgus Foot

Calcaneovalgus foot usually is a packaging defect that resolves with time and stretching exercises. It is associated with external tibial torsion, similar to the association of metatarsus adductus with internal tibial torsion. Clinically, the feet appear “flat,” the heelbone is angled away from mid-line, and the ankles rest in dorsiflexion. If the foot cannot be manipulated easily into plantar flexion, the clinician must rule out congenital vertical talus, a relatively rare condition in which the talus is malaligned that must be treated operatively.

### Pes Planus

Pes planus is known colloquially as flat feet and sometimes is referred to as “plano valgus” feet. Flexible pes planus, in which the feet reform an arch when the patient stands on his or her toes, is an inherited (autosomal dominant) variation of normal associated with generalized ligamentous laxity. The chief complaint often is that the child’s “ankles cave in.” This condition had been believed to contribute to back and knee problems later in life, but no evidence supports this contention. Treatment usually is unnecessary. Most practitioners prescribe arched shoe inserts only if the patient complains of pain. Reassuring the family that this is not a serious or dangerous condition typically is the major component of intervention.

Rigid pes planus, in which the arch does not reform with the patient on his or her toes and in which the subtalar joint has limited motion on examination, is less common and more often symptomatic. Among children and adolescents, the cause usually is a tarsal coalition, in which one or more of the tarsal bones, which should have a joint between them, become fused. The lack of motion in the fused area puts more stress on the neighboring joints that are still open, causing pain. Tarsal coalitions often become symptomatic in early adolescence because prior to that age the fused joints are cartilaginous, not bony, and still are relatively flexible. Although some coalitions can be seen on plain radiographs, computed tomography frequently is the best diagnostic study.

Early treatment for a tarsal coalition can be symptomatic, using immobilization to decrease pain. However, because coalitions are essentially mechanical problems, they respond best to operative treatment for removal of the bony blockage and restoration of motion through the affected joint.



Figure 6. The Ortolani test.

## Hip Disorders

### Developmental Dysplasia of the Hip (DDH)

DDH is a spectrum of abnormalities of the developing hip joint that ranges from shallowness of the acetabulum to capsular laxity and instability to frank dislocation. DDH previously was known as congenital dislocation of the hip, but it now is understood that the condition is not purely congenital; it changes and develops over time. For this reason, it is critical that children be examined for DDH not only in the immediate newborn period, but also periodically at least until walking age.

DDH is relatively common, occurring in 1:1,000 live births. Risk factors include being female, being first-born, having been carried or delivered in the breech position, and having a family history of hip dysplasia or ligamentous laxity. The last two factors are the most significant. The screening examination for DDH consists of looking for asymmetries in the number of skin folds in the thigh, range of abduction, and height of the affected knee (the Allis or Galeazzi sign). There also are two “provocative” tests, the Ortolani (Fig. 6) and Barlow (Fig. 7), designed to elicit “clunks” that represent movement of the femoral head in and out of the acetabulum. There is some confusion in the literature concerning the difference between hip “clicks” and “clunks,” which can be referred back to difficulties in translating Ortolani’s original paper from Italian into English. However, with some practical experience, the difference becomes clearer because a true “clunk” has a specific feel. “Clicks,” which

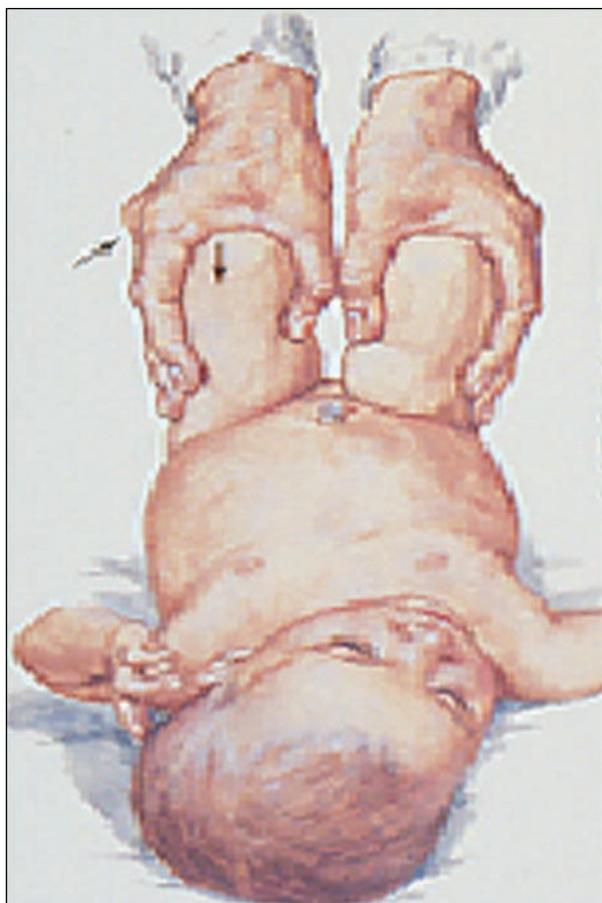


Figure 7. The Barlow test.

often produce a high-pitched snapping sound, usually represent the iliotibial band passing over the greater trochanter. They resolve with growth and are present in 15% of infants who do not have DDH.

Both the Ortolani and Barlow tests are performed with the infant lying supine on a relatively firm surface. The child's diaper should be removed. The Ortolani test relocates a dislocated hip and is performed by the examiner placing his or her fingers on the greater trochanters and thumbs on the knees, abducting the legs and lifting up on the trochanters. As the femoral head reduces into the acetabulum, the examiner will hear and feel a "clunk." The Barlow test dislocates the hip and is performed by placing the hands in the same position as for the Ortolani test, but adducting the legs and pushing down on the knees. A similar "clunk" will be felt as the femoral head dislocates. When infants reach about 3 to 4 months of age, both tests become difficult to perform and interpret. At that age, decreased abduction and a positive Galeazzi sign may be the only remaining physical

findings of a DDH. Because most of the screening examination for DDH is based on discerning asymmetries between the affected and unaffected sides, cases of bilateral DDH can be particularly difficult to diagnose.

A large portion of the pelvis and hips is not ossified at birth, making plain radiographs relatively useless in diagnosing DDH until a child is 4 to 6 months of age. Until that time, the imaging study of choice is ultrasonography of the hips, which should be performed when the child is at least 4 to 6 weeks old to avoid false-positive results.

It is important to remember that DDH can be difficult to diagnose, and up to 5% of cases are missed by experienced examiners. It is, therefore, important not only to examine patients repeatedly during the first postnatal year, but also to have a low threshold for referring patients in whom examination results are equivocal. Interestingly, in the absence of other disabilities, DDH does not cause significant functional disability in children, even when the diagnosis is missed or delayed. Children who have isolated DDH reach their developmental milestones on time, and they ambulate without difficulty. However, if left untreated, DDH may lead to severe early degenerative hip arthritis. Therefore, the goal of early definitive treatment of DDH is to prevent future degenerative changes.

Treatment is designed to relocate and stabilize the femoral head in the acetabulum. The method of accomplishing this varies by age at diagnosis, but generally treatment is simpler and more effective the earlier it is begun. Until the age of 6 months, a bracing device called a Pavlik harness is usually effective (Fig. 8). The Pavlik harness holds the infant's hips in the "human position," which is approximately 45 degrees of abduction, 100 degrees of flexion, and 20 degrees of external rotation. A body cast in a similar position frequently is necessary for children between 6 and 12 months of age; beyond 1 year of age, most patients require surgery to reseat the hip. Children who have been treated for DDH should be followed at least until they walk to ensure continued normal development of the hip joint.

### Slipped Capital Femoral Epiphysis (SCFE)

SCFE is displacement of the femoral head in relation to the femoral neck through the growth plate during a period of rapid growth in adolescence. Children usually have a history of insidious pain or limp, but the onset also can be acute. The typical patient is seen in pre- or early adolescence, with the average age at diagnosis being 11 to 13 years for girls and 13 to 15 years for boys. Because SCFE can be related to hormonal disorders, children diagnosed at younger than 10 years of age or

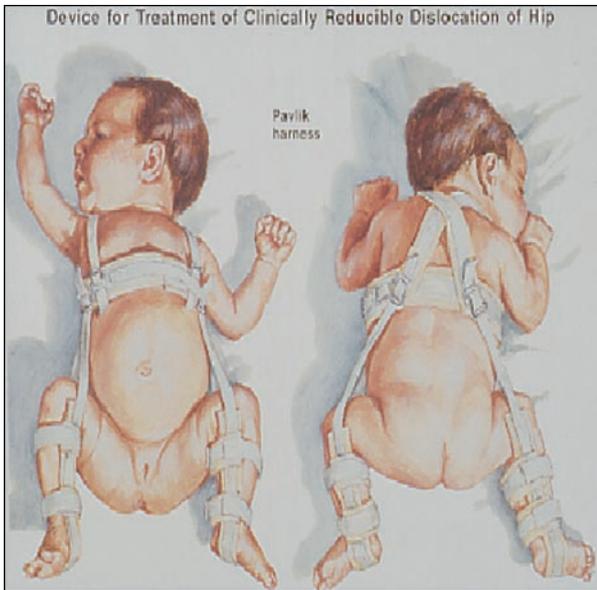


Figure 8. The Pavlik harness.

those who are in the lowest 10th percentile for height should receive an endocrine evaluation.

SCFE is more common in African-Americans than in Caucasians, and although the “typical” patient body habitus is obese, up to one third of affected patients are not. In fewer than 50% of affected children, the pain is localized to the groin, which is the location of the hip joint. Most of the remainder of patients complain of pain in the knee or thigh because a branch of the obturator nerve originating in the hip joint ends in the knee joint capsule, thus referring the pain. Therefore, the clinician must rule out hip pathology in any child complaining of knee or thigh pain. This is of utmost importance because hip disorders in children generally are more serious than knee problems and need to be diagnosed and treated in a timely fashion.

The physical examination findings in SCFE are ambulation with a limp, external rotation of the foot on the affected side, external rotation that accompanies hip flexion, and internal rotation of the hip that is limited or painful. The diagnosis typically is made by obtaining anteroposterior (AP) and frog lateral radiographs of the pelvis. The deformity usually is viewed better on the lateral radiograph (Fig. 9). It is imperative to obtain views of both sides because in 20% of cases, SCFE is bilateral at diagnosis, although one side frequently is asymptomatic. An additional 30% of patients present with a slip on the contralateral side within 1 year.

The treatment for SCFE is placement of one or two metal screws across the growth plate of the affected hip to



Figure 9. Radiographic appearance of slipped capital femoral epiphysis.

prevent further slip (Fig. 10). If the slip is “stable” and allows the patient to bear weight, one pin is used. If the patient is in so much pain that he or she cannot bear weight, the slip is termed “unstable,” and two pins are inserted. The pinning is done “in situ,” meaning that no attempt is made to reduce the epiphysis back to its original position; such maneuvers have been found to damage the blood supply to the femoral head, which can lead to avascular necrosis. Prophylactic pinning of the contralateral side in cases of unilateral SCFE remains very controversial.

### Legg-Calvé-Perthes Disease (LCP)

Typically known as Perthes disease, LCP is idiopathic avascular necrosis of the femoral head. The cause is

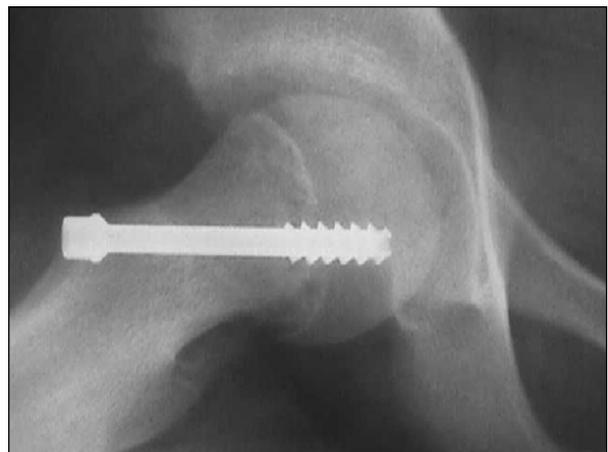


Figure 10. Radiographic appearance of slipped capital femoral epiphysis after pinning.



Figure 11. Radiographic appearance of Perthes disease.

unknown, although the onset of disease probably is multifactorial, with an underlying genetic or hormonal predisposition and an external catalytic (often traumatic) event. The typical patient is a 4- to 8-year-old boy who is somewhat small for his age and very active, has an insidious onset of a limp, and may experience associated pain. As in SCFE, the pain often is localized to the knee or thigh, rather than the hip.

The physical examination findings of the affected extremity are very similar to those of SCFE, with limited abduction and internal rotation of the hip, and AP and frog lateral pelvic radiographs are diagnostic (Fig. 11). Typically, the affected side shows sclerosis, flattening, and fragmentation of the femoral head. The disease runs a course of about 2 years from the time of diagnosis, in which the femoral head fragments, subsides, then slowly reforms.

Treatment for LCP is somewhat controversial; there are advocates for physical therapy, bracing, and various types of surgery. At present, there is no method of changing the underlying disease process; all treatments are aimed at maintaining the range of motion of the hip and roundness of the femoral head during the period of regrowth. Because reshaping and remodeling of the femoral head continues throughout the patient's growth stages, the prognosis is better when LCP is diagnosed at a young age.

LCP is rarely bilateral (10% of cases), and in such cases, the two hips never are affected symmetrically. Patients who have a radiographic appearance of bilateral, symmetric hip avascular necrosis should be evaluated for hemoglobinopathy or skeletal dysplasia.

### Coxa Vara and Valga

Normally, the angle that the femoral neck makes with the femoral shaft is about 130 to 135 degrees. If the neck-shaft angle is less than normal, the hip is said to be in varus; if it is greater than normal, the hip is in valgus. Both coxa vara and coxa valga can lead to early osteoarthritis of the hips.

Congenital coxa vara arises from a defect in the ossification of the femoral neck. It is bilateral in one third to one half of cases. Most patients are diagnosed between the ages of 2 and 6 years, when it is noted that they have either a limp or a waddling gait. Some patients have a concomitant leg length discrepancy. As in most hip disorders, the range of motion of the hip is restricted, particularly in abduction and internal rotation.

AP and frog lateral pelvic radiographs are diagnostic, and the outcome can be predicted by the orientation and positioning of the proximal femoral physis. In cases of coxa vara in which spontaneous correction with growth is not anticipated, treatment consists of a proximal femoral osteotomy to restore the normal neck-shaft angle. Coxa vara also can be one manifestation of dysplasia or hemoglobinopathy or can be acquired following damage to the femoral neck or physis due to trauma or infection.

Coxa valga generally is associated with an underlying disorder, such as DDH or spasticity of the adductors, but it can be congenital. Coxa valga frequently is asymptomatic in children, making diagnosis difficult. The child may present with increased internal rotation and adduction of the hips, particularly if adductor spasticity is the underlying cause. As with coxa vara, the underlying goal of treatment for coxa valga is to restore the normal neck-shaft angle, with surgery, if necessary, to prevent painful osteoarthritis in early adulthood.

### Toewalking

Toewalking may occur as a normal phase in gait development. Children generally develop a heel-toe gait by the age of 3 years; toewalking beyond the age of 4 years is considered abnormal. Prolonged toewalking may be due to an underlying neurologic disorder, such as cerebral palsy, tethered spinal cord, muscular dystrophy, intraspinal lesion or tumor, or acute myopathy. Some children may walk on their toes with no underlying pathology, a condition sometimes referred to as "idiopathic" toewalking. Other children toewalk as a result of tight heel cords.

If the birth history, past medical history, and physical examination of a child who is toewalking raise suspicion about a neurologic problem, appropriate diagnostic and treatment measures should be taken. A child who

toewalks and has increased muscle tone may have cerebral palsy. In contrast, an idiopathic toewalker demonstrates a foot that is easily dorsiflexed, can comfortably stand with the foot plantigrade, and has no lower extremity spasticity or hyperreflexia.

Treatment of toewalking per se is similar regardless of cause: physical therapy to stretch out the Achilles tendon, followed by ankle-foot orthoses to maintain tendon length. If stretching exercises alone do not lengthen the tendon, serial stretch casting (new casts every 2 wk for 4 to 8 wk) frequently is successful. Botulinum toxin injections may help to decrease muscle tone for 4 to 6 months and can be useful as an adjunct to stretch casting. However, botulinum toxin rarely constitutes definitive treatment alone. Finally, surgical lengthening of the tendon (followed by bracing) is employed when other modes of treatment have failed. The length of time required for bracing varies; generally, the need is reassessed each time a child outgrows his or her braces.

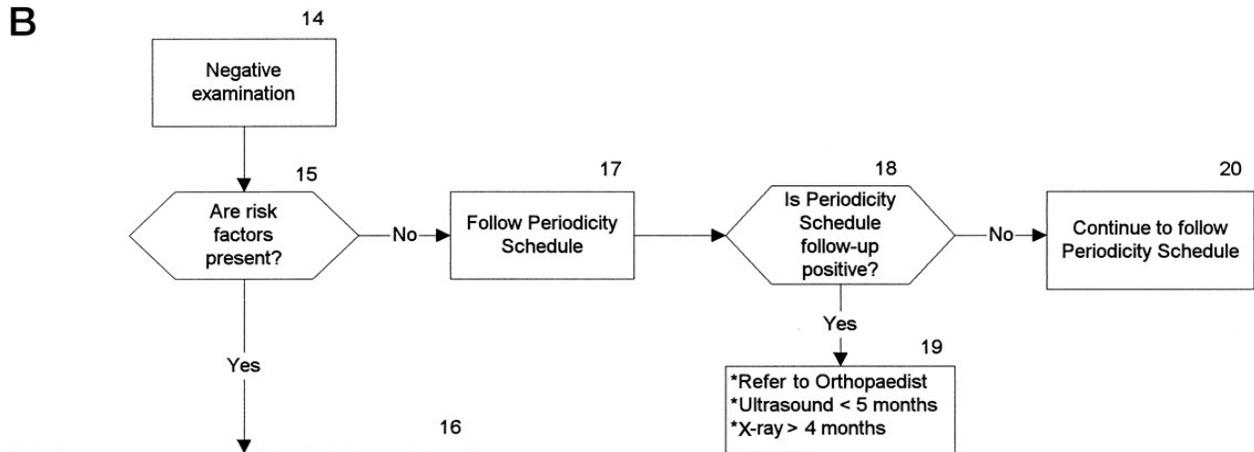
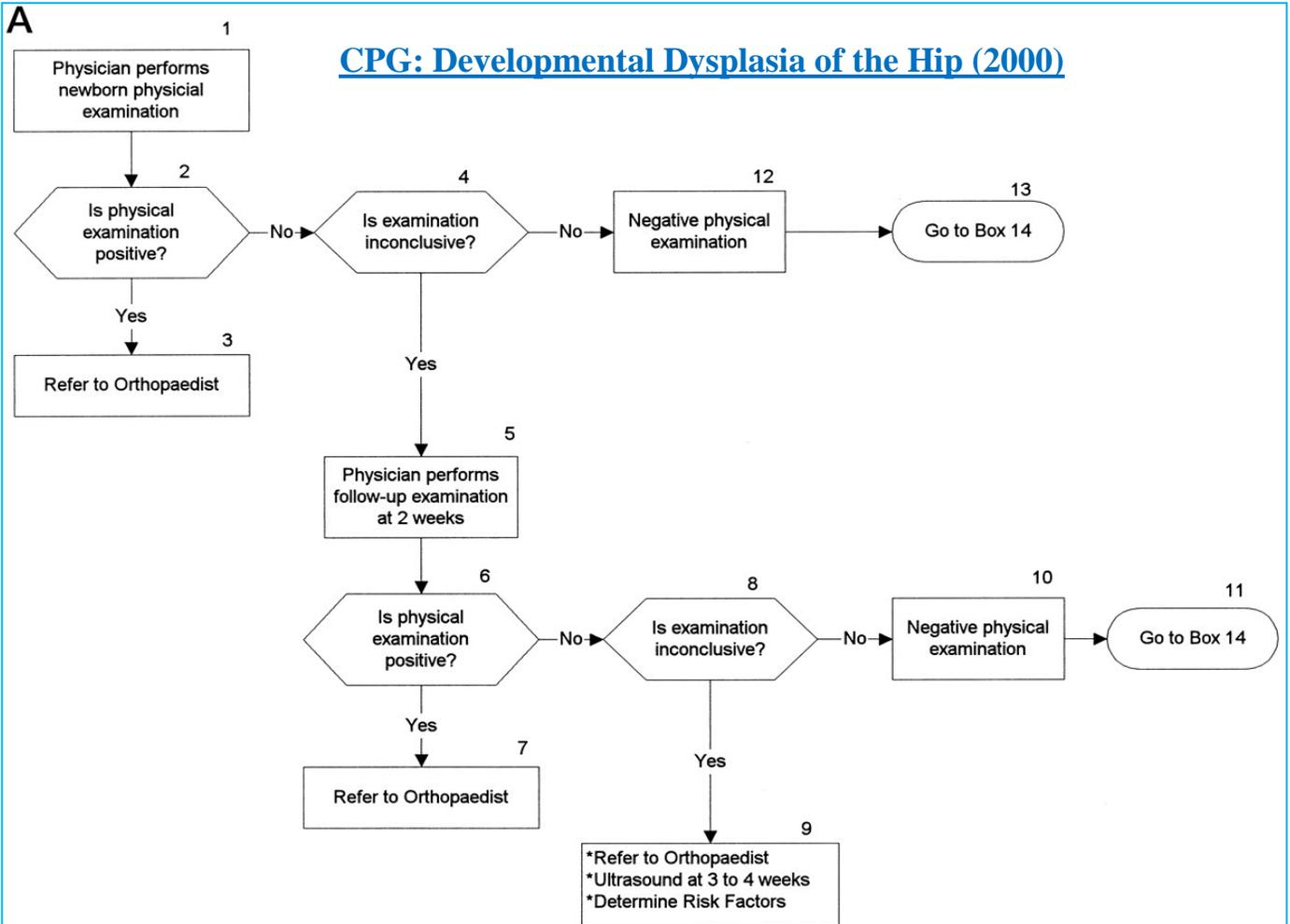
## Conclusion

There is a broad range of common lower extremity problems in children. Many of the rotational and angular deformities are physiologic and resolve spontaneously. Foot deformities may be of cosmetic concern only or of functional significance, requiring treatment. Hip disorders generally are more serious and require prompt diagnosis and initiation of treatment. Hip pathology may present as thigh or knee pain, necessitating a high index of suspicion in the case of a child whose chief complaint is thigh or knee pain.

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## CPG: Developmental Dysplasia of the Hip (2000)



<u>RISK FACTOR</u>	<u>RECOMMENDED ACTION</u>	<u>Absolute Risk:</u>
Girl	Follow Periodicity Schedule	19/1000
Family History and Boy	Follow Periodicity Schedule	9.4/1000
Family History and Girl	Optional future imaging	44/1000
Breech and Boy	Optional future imaging	26/1000
Breech and Girl	Recommend future imaging	120/1000

## CPG: Developmental Dysplasia of the Hip, *continued*

(Adapted from full AAP CPG—see Extra Credit Link)

- 1a. *All* newborns are to be screened by physical examination.
- 1b. Ultrasonography of *all* newborns is *not* recommended.

### Newborn Physical Examination and Treatment

- 2a. If a **positive Ortolani or Barlow sign** is found in the newborn examination, the infant should be **referred to an orthopedist**. The precise time frame to be evaluated by the orthopedist cannot be determined from the literature—refer if abnormalities still present at 2 weeks.
- 2b. If exam at birth is “**equivocally**” **positive** (ie, soft click, mild asymmetry, but neither Ortolani nor Barlow is present), then a follow-up hip examination in 2 weeks is recommended.
- 3a. If the results of the newborn **physical examination are positive** (ie, presence of an Ortolani or a Barlow sign), ordering an **ultrasonographic examination is not recommended**.
- 3b. If the results of the newborn **physical examination are positive**, obtaining a **radiograph of pelvis and hips is not recommended**—of limited value and do not influence treatment.

### 2-Week Examination

4. If the results of the **physical examination are positive** (eg, positive Ortolani or Barlow sign) at 2 weeks, **refer to an orthopedist**. Referral is urgent but is not an emergency.
5. If at the 2-week examination the Ortolani and Barlow signs are absent but **physical findings raise suspicions** (eg, adventitial click, thigh asymmetry, and apparent leg length difference), consider **referral to an orthopedist or request ultrasonography at age 3 to 4 weeks**.
6. If results of the **physical exam are negative** at 2wks, follow-up at scheduled well-baby visits.
7. If the results of the exam are **negative (or equivocally positive)**, consider **risk factors**:
  - (A) **Girl**: Evaluate as newborn and at 2 weeks. If results are negative, follow periodicity schedule. If positive, refer to ortho or for U/S at *3 weeks of age*.
  - (B) **Infants with a positive family history of DDH**:
    - For boys, if exam is negative or equivocally positive, hips should be reevaluated at 2 weeks. If positive, refer to ortho or for ultrasonography at *3 weeks of age*.
    - For girls, image with an *U/S at 6 wks* or a radiograph of the pelvis at *4 months*.
  - (C) **Breech presentation**
    - For negative or equivocally positive newborn exams, reevaluate at regular intervals if the examination results remain negative.
    - For girls, ultrasound at *6 weeks of age* or with a radiograph of the pelvis and hips at *4 months of age* is recommended. This is an option for boys too. (*See abs. risk*)
8. **Periodicity**. The hips must be examined at every well-baby visit according to the periodicity schedule. If during follow-up DDH is suspected due to abnormal exam or parental complaint, confirm with *U/S if the infant is younger than 5 mo*, or by *X-ray if the infant is older than 4mo*.

## Lower Limb Deformities Quiz

1. True or False: In-toeing and out-toeing in most children are due to physiologic variations of normal lower-extremity development that will improve spontaneously without intervention.

2. The **most common causes of in-toeing** in children are: \_\_\_\_\_

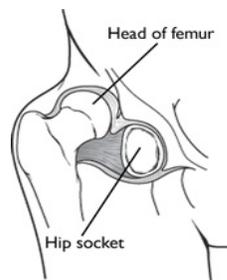
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3. **Developmental dysplasia of the hip** may present with in-toeing due to: \_\_\_\_\_

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4. **Developmental dysplasia of the hip** occurs:

- a. In utero
- b. Perinatally
- c. During infancy
- d. During childhood
- e. All of the above



5. The \_\_\_\_\_ position in utero places the newborn at highest risk for **DDH**. The \_\_\_\_\_ hip is involved more often when in a vertex position. Females are affected more/less often than males.

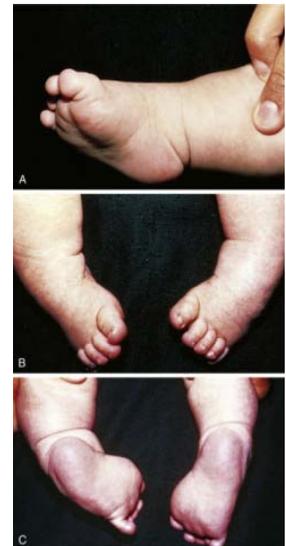
6A. True or False: There is an association between **DDH** and **metatarsus adductus**.

6B. True or False: There is an association between **DDH** and **clubfoot**.

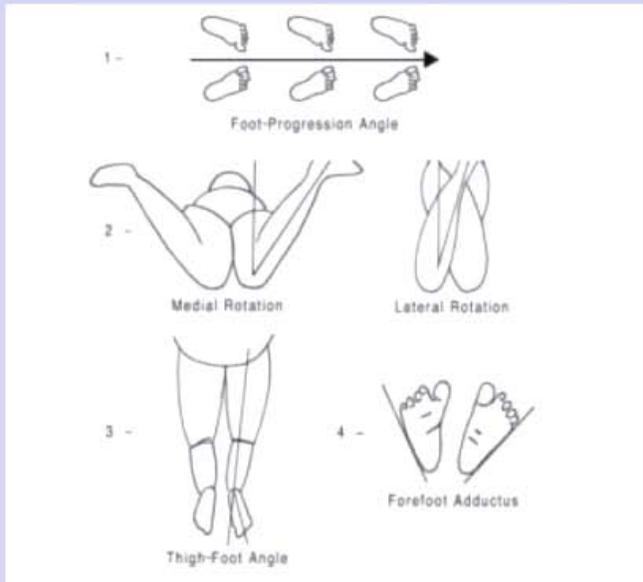
7. **Clubfoot** occurs with a frequency of \_\_\_\_\_ live births with \_\_\_\_\_ of cases bilateral. It is more common in \_\_\_\_\_ and is often \_\_\_\_\_ inheritance.

8. List the **four deformities** that create a clubfoot.

9. Discuss the **treatment options** for clubfoot correction.



## Rotational Profile: Hands-on Demo



### Rotational Profile Helps Differentiate Conditions That Cause Intoeing

Measuring a child's rotational profile and comparing values with published normal values can differentiate conditions that cause intoeing and determine the level and severity of the problem. The rotational profile includes several measurements.

- 1) Foot progression angle (FPA) is the number of degrees the foot turns in or out relative to the direction of walking. Intoeing values have a minus sign preceding the number of degrees. Usually, mild intoeing is 0 to -10 degrees; moderate is -10 to -20 degrees; and severe is more than -30 degrees. When estimating the FPA, focus on one foot at a time, because the FPA will often change with each step.
- 2) Arc of hip rotation measures the arc of motion with the child in a prone position. Flex the knees to a right angle and rotate both thighs concurrently. Let the limbs fall to the level of maximum rotation without force. Measure both the medial and lateral rotation. When measuring lateral rotation, make sure the child's legs are crossed. Measure the maximum rotation at the vertical tibial angle. During childhood, the upper range of medial rotation is about 70 degrees for girls and 60 degrees for boys. Beware of asymmetric hip rotation, which is often a sign of hip disease.
- 3) Thigh-foot angle (TFA). This is a measure of tibial rotation. With the foot in resting position, estimate the angle by comparing the axis of the foot with that of the thigh. The TFA rotates more laterally with increasing age. Infants often have a minus value for TFA. Medial tibial torsion is present when a minus value during childhood or the teen years falls outside the normal range. The upper range of normal is about +30 degrees. Values beyond that level are abnormal and are described as lateral tibial torsion.
- 4) Foot. With the child in a prone position, the shape of the sole of the foot is easily assessed. Normally, the lateral border is straight. A convex lateral border indicates forefoot adductus.

### 1) Foot progression angle (FPA)

R \_\_\_\_\_

L \_\_\_\_\_

### 2) Femoral anteversion

#### a) Medial rotation

(internal rotation of hip)

R \_\_\_\_\_

L \_\_\_\_\_

#### b) Lateral rotation

(external rotation of hip)

R \_\_\_\_\_

L \_\_\_\_\_

### 3) Thigh-foot angle (TFA)

R \_\_\_\_\_

L \_\_\_\_\_

### 4) Foot abduction and adduction with heel-bisector line (HBL)

R \_\_\_\_\_

L \_\_\_\_\_

## Lower Limb Deformities Mega-Case

### Part 1:

A mother brings her 2 week old AA daughter Erin in for her routine check-up. Erin was born to a 27 year old G3P2 at 38 weeks via C/S due to breech position and failed ECV. Prenatal course and birth were otherwise uncomplicated. Erin was discharged home with her mother after 3d. She has been breastfeeding since discharge with appropriate weight gain.

Her mother is concerned today about her legs. She remembers that Erin is at risk for DDH and wants to know how she will be screened. Also, she read online that there can be an association between DDH and clubfeet. She is worried that Erin has clubfeet as her feet are bent inward. Mother also mentions that she had DDH and wore a brace as an infant, but there is no family history of clubfeet. Erin's 4 year old brother is healthy with normal development and growth.

Erin's physical exam is overall normal. Her legs are held in a slightly flexed and abducted position at rest. There is symmetric movement with the Moro and no leg length discrepancy. Ortolani and Barlow tests conducted while she is calm are negative for clunks as well as clicks. Her feet are convex along the lateral borders giving them a "bean shaped" appearance. There is a slight transverse crease medially. Lightly stroking the outside of her foot does not lead to a change in the shape but her foot can be passively straightened. There is no other foot deformity.

**Based on the history and exam, what type of screening would you recommend to Erin's mother regarding DDH?**

**Based on the exam, what is the most likely deformity of Erin's feet? What, if any, interventions would you recommend?**

### Part 2:

Erin's metatarsus adductus eventually resolves with passive stretching and screening ultrasound of her hips at 6 weeks is normal. Her family PCS's to Georgia and you follow the next year. You reunite at her 2 year-old well visit. Her growth and development have been appropriate; however, her mother is very concerned because her "legs are bent and pointing inward." The deformities seem to cause her to trip a lot and her mother would like recommendations for braces or inserts to help correct the deformities. Erin does not complain of any leg pain.

**How would you proceed with evaluation of Erin's legs?**

Erin's exam is most consistent with internal tibial torsion and genu varum. **How would you counsel her mother and address the need for treatment?**

Part 3:

Given her mother's concern you follow Erin every 6 months to monitor her torsion and genu varum for the next few years until both deformities eventually correct themselves. However at her pre-kindergarten visit her mother remarks that she still in-toeing. Reevaluation demonstrates increased internal rotation of both hips. **What is the most likely cause of Erin's intoeing at this point and how would you counsel her mother now?**

Part 4:

By age 15 Erin's rotational and angular deformities have all resolved. She is a freshman in high school and excelling on the varsity track and field team. She presents for a routine exam. Her mother's only concern at this point is the type of shoes Erin is wearing and whether they offer adequate support for her flat feet. Erin denies any pain in her feet however her mother would like further evaluation for orthotics just in case. **How do you further evaluate Erin's feet?**

Exam is consistent with flexible pes planus. What type of interventions would you recommend?

## In-toeing & Out-toeing Board Review

*Questions from PREP 2008 & Pediatrics Board Review Series (2005)*

1. The parents of a 6-month-old boy are concerned because his feet “turn in”. They noticed his “pigeon” toes since he was a few months old. On examination the infant’s mid-foot curves inward but can be straightened by gentle manipulation, even beyond midline.

**Which of the following is the most appropriate treatment?**

- (A) Reassurance only
- (B) Referral for corrective orthopedic shoes
- (C) Prescription of special shoes that are connected by a bar to point the toes outward
- (D) Referral for casting
- (E) Referral to pediatric orthopedic surgery for operative repair

2. The parents of a 4-year-old boy are concerned about their son’s bowed legs. The bowing has been apparent ever since he began to walk. However, they are a bit concerned now because the bowing in his right leg has become more pronounced, while his left leg appears to be improving. On physical examination, the right leg is bowed laterally to a greater degree than his left leg, and when he walks, his body shifts laterally away from midline.

**Which of the following is the most appropriate management of this patient?**

- (A) Standing anterior-posterior radiograph of the lower extremities.
- (B) Referral for physical therapy to strengthen the muscles of the lower extremities
- (C) Parental reassurance that the condition is genu varum and will resolve without treatment
- (D) Parental reassurance that the condition is genu valgum and will resolve without treatment
- (E) Referral to a podiatrist for orthotic shoes

3. An 18-month-old girl who has been adopted from Russia presents to your office for an initial health supervision visit. The mother notes that the girl limps, and she thinks one leg is longer than the other. There is no history of medical attention for this problem in the adoption documentation. Review of available medical history and the current physical examination reveal no signs of illness. The child appears to be otherwise growing and developing normally. On physical examination, you measure a leg length discrepancy of 2 cm, and the girl has a “waddling” type limp and difficulty in abducting her right thigh at the hip.

**Of the following, the MOST likely diagnosis is**

- (A) developmental dysplasia of the hip
- (B) femoral anteversion (internal femoral torsion)
- (C) Legg-Calvé-Perthes disease
- (D) slipped capital femoral epiphysis
- (E) vitamin D-dependent rickets

4. You are evaluating an 18-month-old child who has an obvious limp in a clinic for adoptees from foreign countries. Perinatal and other medical history are not available. The child's gait is characterized by a 'drop' in stance when walking on one side, with the affected femur appearing shorter than the other. Physical examination reveals no other abnormalities. A radiograph of the hips is obtained.

**Of the following, the MOST likely cause of this child's findings is**

- (A) DDH
- (B) Coxa vara deformity
- (C) Femoral anteversion
- (D) Healed fracture
- (E) Legg-Calve-Perthes disease



5. A 4-year-old boy is brought in for evaluation by his mother. He has had “intoeing” all of his life, and his grandmother took him to a doctor who prescribed expensive corrective shoes, but he has not improved. Physical examination reveals no metatarsus adductus or tibial torsion. You note that he likes to sit on his knees with his legs behind him in a “W” shape.

**Of the following, you are MOST likely to find on completely unclothed examination**

- (A) bowed legs
- (B) equinovarus deformity
- (C) femoral anteversion
- (D) pain over the tibial tuberosity
- (E) waddling gait