CHAPTER 4

David D. Aronsson
Jennifer W. Lisle

The Pediatric Orthopaedic Examination

INTRODUCTION

The pediatric orthopaedic examination can vary considerably depending on the age of the child, chief complaint, magnitude of the problem, and the level of concern of the patient and family. In all situations, the clinician should respect the dignity of the child, family, and other health care professionals that accompany the patient. It is important for the child to feel comfortable in the office environment, so having a bright child-friendly waiting room with toys and age-appropriate books can be very beneficial. It is helpful to have the family or caregivers fill out a patient intake form (Fig. 4-1) prior to the visit to expedite the history so the clinician can focus on engaging the child and gaining the child's trust. In some cases, this may be the most important aspect of the pediatric orthopaedic examination, as it is almost impossible to perform an adequate examination on an uncooperative child. Currently, the paper chart is gradually being replaced by the electronic medical record (EMR). In cases where the EMR is utilized, patients and their families can fill out the patient intake form electronically at home through a security enable portal, or through special computer kiosks, set up in the waiting room. Many hospitals, including ours, are mandating that patients or families fill out a pain assessment form such as the Wong-Baker FACES pain rating scale.

Recent studies have shown that clinician–patient communication underlies successful medical care, yet medical training has paid little attention to the importance of developing communication skills. Research has shown that improved communication improves diagnostic accuracy, fosters shared decision making, and increases the likelihood that the patient will follow the treatment recommendations. In addition, patient and clinician satisfaction increases and the risks of malpractice litigation decrease. The American Academy of Orthopaedic Surgeons (AAOS) has developed the "Clinician-Patient Communication to Enhance Health Outcomes Workshop" to address communication skills.

The AAOS approach identifies the different goals of the clinician and patient and emphasizes how they can all be addressed with improved communication. While the clinician wants to solve the problem with the "find it" and "fix it" approach, the patient has already made a self-diagnosis and wants the clinician to address an agenda of concerns including the self-diagnosis. To achieve the medical goals, the clinician needs to use the "4 Es" of communication skills: engage, empathize, educate, and enlist. To "find it," the clinician must engage and empathize with the patient and not interrupt them while they are explaining their agenda. If this person-to-person or professional–partner engagement is attained, the accuracy of the diagnosis is improved and the "fix it" is achieved by improved patient education and enlisting the patient in shared decision making in the treatment. Improved communication results in improved patient outcomes. In today's world, parents and young people expect to be heard, and their input often helps the clinician work with them.

The clinician begins by introducing himself or herself to the patient and family. If a resident physician or medical student accompanies the clinician into the exam room, it is important to introduce them and explain that they are learning. The clinician sits down to make direct eye contact with the child and listens attentively while taking an accurate history from the patient, family, and caregivers. Although a brief history and limited physical examination may be appropriate for a 5-year-old boy with a torus fracture, a complete history and physical examination are necessary to evaluate a 2-year-old boy who is still not walking.

HISTORY

The history always should begin with the *chief complaint*, a sentence or short statement in the exact words of the patient. If the patient is nonverbal or not yet talking, the chief complaint can be recorded in the exact words of the family or caregivers.

The *history of present illness* includes the details of how and when the chief complaint started and whether the symptoms are constant or intermittent. The clinician asks how the symptoms have evolved and if there are certain circumstances that aggravate the symptoms, such as exercise, or certain circumstances that relieve the symptoms, such as rest. It is important to document if any prior treatment has been recommended or rendered.

Age: Years _____ Months _____ Grade in School _____
Brothers _____ Sisters _____
Height of Mother: _____ Height of Father: _____
Referring Physician: _____ Family Physician: _____

What is the reason for today's visit? _____
When did this problem first start? _____
Is it better, worse or the same from when you first noted it? _____
Have you had any treatment? _____
If yes, please list the treating physician(s) and treatment _____

Past History:

Medical Problems?	Yes _____	No _____	If yes, please list	_____
Operations?	Yes _____	No _____	If yes, please list	_____
Medications?	Yes _____	No _____	If yes, please list	_____
Drug Allergies?	Yes _____	No _____	If yes, please list	_____
Latex Allergies?	Yes _____	No _____		_____
Other Allergies?	Yes _____	No _____	If yes, please list	_____

Birth History of Patient:

Premature?	Yes _____	No _____	Reason?	_____
Problems?	Yes _____	No _____	Reason?	_____
Breech?	Yes _____	No _____	Reason?	_____
Caesarian?	Yes _____	No _____	Reason?	_____

Birth Place: _____ Hospital: _____ Birth weight: _____ lbs. _____ oz.

Developmental Milestone of the Patient:
At what age did the child:
Roll over? _____ months Sit up? _____ months Walk? _____ months

Family History of Patient:
Please describe any family history of medical problems related to patient's condition:

_____
_____

Social History of Patient:
Please describe any sports or extracurricular activities:

_____

General Conditions/Treatments

Yes	No		Yes	No	
_____	_____	frequent or severe headaches	_____	_____	dizziness
_____	_____	blurring or other problems with vision	_____	_____	bladder problems or infection
_____	_____	hearing difficulty	_____	_____	cancer
_____	_____	shortness of breath or wheezing	_____	_____	diabetes
_____	_____	chest pain or palpitations	_____	_____	blood clots or phlebitis
_____	_____	abdominal pain, nausea or vomiting	_____	_____	high blood pressure
_____	_____	abdominal bleeding	_____	_____	stroke
_____	_____	depression	_____	_____	thyroid gland disorder
_____	_____	persistent or repeated rashes	_____	_____	epilepsy or seizures
_____	_____	repeated fevers	_____	_____	weight loss or gain
_____	_____	arthritis			
_____	_____	Other: _____	If yes, please explain briefly: _____		

FIGURE 4-1. Patient intake form. This form, when filled out by the patient or family, prior to the office visit can save valuable time while conducting the history and physical examination.

The *past medical history* includes any prior major illnesses, hospitalizations, operations, and if the patient is taking any medications. The patient's medications are reconciled and the patient's allergies are recorded, particularly any allergies to medications.

The *developmental history* includes the details concerning the pregnancy, delivery, and perinatal course. Any complications associated with this pregnancy or any prior pregnancies are documented. Any problems associated with the delivery, such as an emergency cesarean section, or the newborn period, such as transfer to the Neonatal Intensive Care Unit (NICU), are noted. The clinician asks the family if anyone has raised concerns about developmental delay and records the developmental milestones, including when the child first sat, pulled to standing, cruised around furniture, walked independently, and developed handedness.

The *family history* focuses mainly on the immediate family including siblings, parents, grandparents, and any other close relatives. The clinician asks if any family members had a similar problem or a major illness.

The *review of systems* includes a general medical overview with questions about each system, such as the respiratory, cardiovascular, or genitourinary systems, to detect any other medical problems. Detecting a medical problem that may be associated with the chief complaint may lead directly to diagnose the problem (e.g., a patient with scoliosis that has a genitourinary problem).

The *personal and social history* reviews the living situation of the patient and may be extremely valuable in diagnosing the problem. The clinician asks about school and sports activities that interest the patient. Hobbies are important as they may reveal more about strengths, relationships, and other issues. Personal questions may be of value since smoking or secondary smoke in the home has been associated with several orthopaedic conditions such as Legg-Calvé-Perthes disease.

PHYSICAL EXAMINATION

The physical examination begins with the height and weight of the patient that is typically performed by the staff prior to placing the patient and family in the exam room. The clinician begins with a thorough examination of the skin, spine, upper and lower extremities, and a brief neurologic examination. The pediatric orthopaedic physical examination does not typically include the vital signs or a detailed examination of the head, eyes, ears, nose, throat, chest, heart, abdomen, or genitals, but any of these areas may require a detailed examination depending on the chief complaint. If there are concerns about certain aspects of the physical examination, these areas are examined in detail.

The history and physical examination varies considerably depending on the age of the patient. Infants and young children are unable to give a history, whereas an older child will often give a more accurate history than the family or caregivers. A teenage boy with a round back may have no concerns, but the family may be concerned that he will develop a severe hunchback deformity like his grandmother. Many pediatric orthopaedic conditions develop only in certain age groups, such as Legg-Calvé-Perthes disease, which typically develops in boys between 4 and 10 years of age. To highlight these important conditions that often develop only in certain age groups, this chapter is divided into three sections, according to the age of the patient. In all cases, once the history and physical examination is completed the clinician should communicate the findings with the referring primary care pediatrician or family physician.

The first section includes newborns, infants, and young children from birth to 4 years of age. These patients are usually unable to give an accurate history, so most of the history is obtained from the family or caregivers. The child may be apprehensive about going to the doctor and afraid of being examined. A toy or sticker may be helpful to divert the child's focus away from the situation and allow the clinician to do a physical examination. The majority of the physical examination of a young child can be done in the mother's lap. Once relaxed, the pertinent aspects of the examination can be performed on the examination table. If the infant is afraid and upset, a pause to allow bottle or breast feeding can be helpful. Once the clinician gains the respect and trust of the child and family, the physical examination can easily be performed.

The second section includes children from 4 to 10 years of age. These patients are not usually afraid and are interested in being a part of the examination. They will often correct their parents or caregivers about certain aspects of the history. They are typically calm and eager to participate and cooperate with the physical examination. In the age group, many children do not like removing their clothes or wearing a hospital gown. This situation can be avoided if the patient wears a T-shirt and a pair of shorts for the office visit. It is helpful to have extra pairs of gym shorts in the office to address this issue. Some children with special health needs are particularly resistant to anyone attempting to conduct a physical examination. In this situation, it is often helpful to tell the family exactly what you would like to accomplish. For example, the clinician can explain to the family that he or she would like to examine the child for scoliosis by having the child bend forward at the waist. The family can then place the child on a relative's lap in the seated position while another family member bends the child forward at the waist to allow the clinician to examine the spine.

The third section includes children and adolescents from 10 to 18 years of age. These patients are usually very motivated to get better and will give an accurate history. Teenagers are also concerned about removing their clothes, so it is reassuring to know that they do not need to remove their T-shirt or shorts. Having extra pairs of gym shorts in the office is again helpful if they come to the office in jeans. If conducted appropriately and in a manner that respects their privacy, teenagers will allow the clinician to perform a complete physical examination. In all age groups, it saves time and avoids repetition to begin by reviewing the patient intake form that was filled out by the family, caregivers, or the patient prior to entering the examination room (Fig. 4-1).

THE ORTHOPAEDIC EXAMINATION FROM BIRTH TO 4 YEARS OF AGE

A 1-Month-Old Girl Is Referred for Evaluation of a Hip Click. A hip click was detected by the pediatrician shortly after birth and was still present at the 2-week appointment. The pediatrician was concerned that the baby might have developmental dysplasia of the hip (DDH) and referred her for evaluation. The history reveals that this is the mother's first child and the pregnancy was normal, but the baby was in the breech presentation and they had to do a cesarean section. The birth weight was 3500 g (7 lb 11 oz) and the baby is otherwise healthy. There is no family history of DDH or hip problems.

A hip click may be a benign click that occurs when the ligamentum teres gets trapped between the femoral head and the acetabulum, or it may indicate a subluxatable or dislocatable hip as is seen in DDH. To distinguish between these two different entities, the clinician focuses on certain aspects of the history and physical examination that are associated with DDH. The birth history may be helpful as DDH is associated with primigravida mothers, oligohydramnios, breech presentations, and congenital muscular torticollis. Of these, the breech presentation is the most important because, even if born by cesarean section, if the infant was in the frank (single) breech presentation, the frequency of DDH is 20% to 30%. The developmental history may reveal that the infant has a neuromuscular disorder, such as arthrogryposis multiplex congenita. The family history is helpful because the frequency of DDH is higher when other family members have the disorder.

The physical examination can be started with the infant in the mother's lap. In this position, the infant is comfortable, and the clinician can examine the range of motion of the hands, wrists, elbows, and shoulders. The neck range of motion is evaluated to rule out a contracture of the sternocleidomastoid muscle that may be secondary to a congenital muscular torticollis. The knees, ankles, and feet are examined to look for any anomalies that might be associated with DDH. The baby can then be placed prone over the mother's shoulder, similar to the position for burping, while the clinician examines the spine. A sacral dimple or hairy patch above the natal cleft may be a sign of an underlying tethered spinal cord or lipomeningocele (Fig. 4-2). These disorders can cause partial paralysis of the lower extremities resulting in a paralytic hip dislocation. Finally, after the rest of the physical examination has been completed, the infant is placed on the examining table to examine the hips.

The key to the early diagnosis of DDH is the physical examination. The examination should be performed on a firm surface with the infant relaxed. If the infant is crying or upset with tensing of the muscles, the DDH may not be detected. In this situation, allow the family to feed or soothe the infant and begin the examination when the infant is calm and relaxed. Barlow recommends the examination be performed in two parts (1).

Part one is termed the "Ortolani maneuver." To perform the Ortolani maneuver, each hip is examined individually

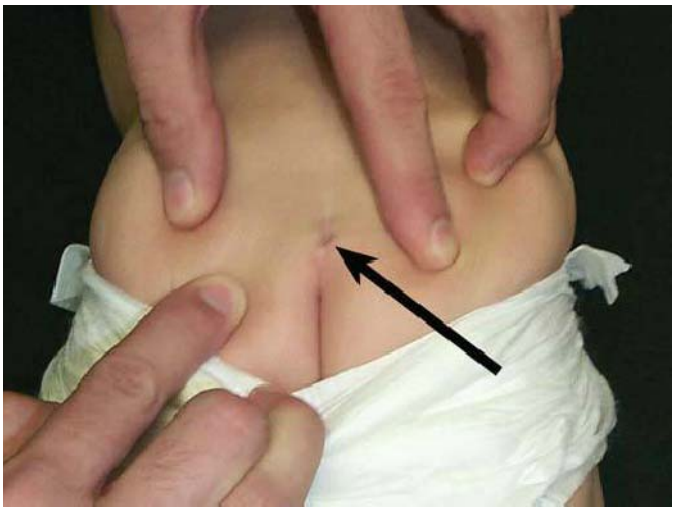

FIGURE 4-2. A sacral dimple (*arrow*) or hairy patch above the natal cleft may indicate an underlying tethered spinal cord or lipomeningocele.

while holding the pelvis steady with the other hand grasping the sacrum and pubic rami, or by using the other hand to hold and stabilize the opposite lower extremity and pelvis. The hips and knees are flexed to 90 degrees and the examiner places the long finger of each hand laterally, along the axis of the femur over the greater trochanter, and the thumb of each hand is placed on the inner side of the thigh opposite the lesser trochanter (Fig. 4-3). With the opposite hip and pelvis stabilized, the thigh of the hip to be examined is carried into abduction with forward pressure applied behind the greater trochanter by the long finger simultaneously. If the femoral head "clunks"

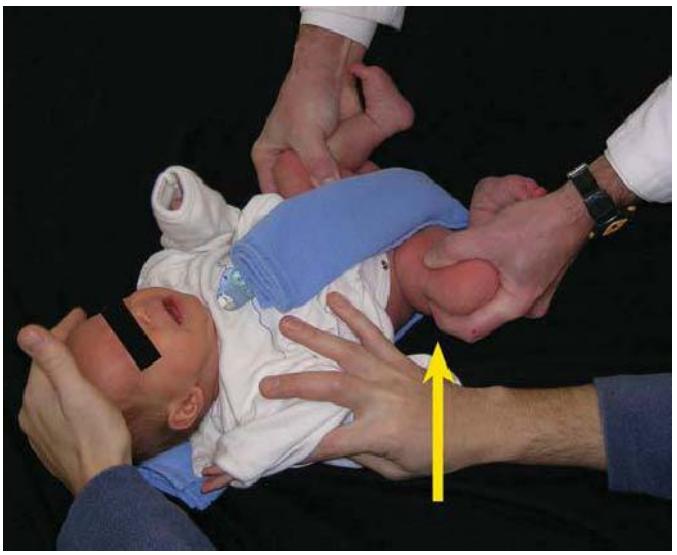

FIGURE 4-3. The first part of the Barlow provocative test is the Ortolani maneuver. This test is performed by gently abducting the hip and pushing forward with the long finger over the greater trochanter (*arrow*). A clunk is palpated as the femoral head slides over the posterior lip into the acetabulum.

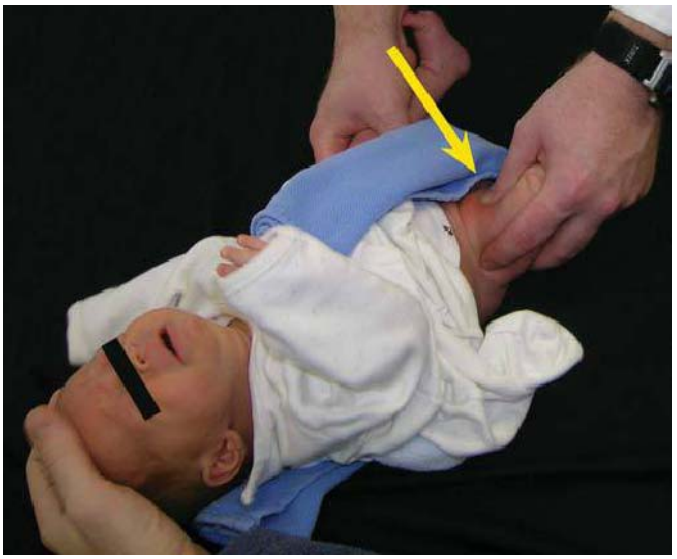

FIGURE 4-4. The second part of the Barlow provocative test involves applying pressure backward and outward with the thumb on the inner side of the thigh (*arrow*) while adducting the hip. If the femoral head clunks or slips out over the posterior lip of the acetabulum and back again after the pressure is released, the hip is unstable.

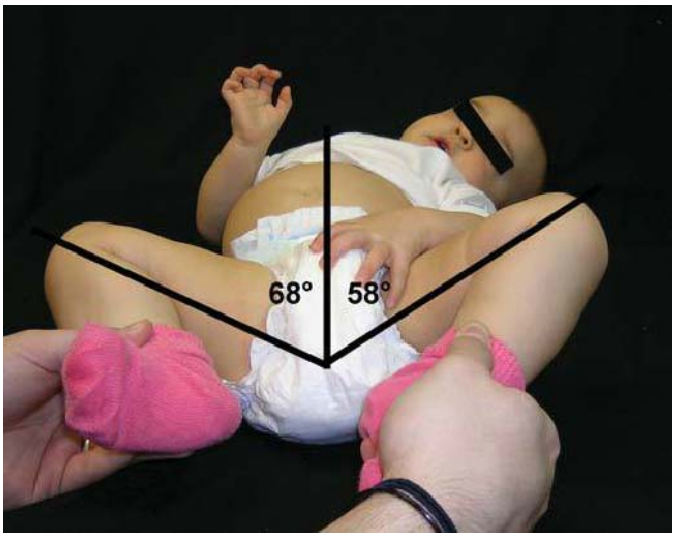

FIGURE 4-5. After 3 months of age, the most common physical finding in a patient with DDH is limited abduction of the hip. The asymmetry may be subtle as in this 15-month-old girl with a dislocated left hip. She has decreased abduction of the left hip (58 degrees) compared with the right (68 degrees).

forward into the acetabulum as the hip is abducted, the hip was dislocated. This maneuver, originally described by Ortolani, represents a "sign of entry" as the femoral head reduces into the acetabulum (Fig. 4-3). The Ortolani maneuver completes the first part of the Barlow test.

Part two of the Barlow test is termed the "provocative test." To perform the Barlow provocative test, each hip is again examined individually. With the hips and knees flexed to 90 degrees, the examiner places the long finger of each hand laterally, along the axis of the femur over the greater trochanter, and the thumb of each hand is placed on the inner side of the thigh opposite the lesser trochanter. With the opposite hip and pelvis stabilized, the examiner applies pressure laterally and posteriorly with the thumb on the inner side of the thigh as the hip is adducted. The hip is unstable if the femoral head "clunks" or slides over the posterior lip of the acetabulum and relocates when the pressure is released. This maneuver represents a "sign of exit," as the femoral head subluxates or dislocates from the acetabulum (Fig. 4-4). In a subluxating hip, the examiner may only detect a sliding sensation as the femoral head slides posteriorly in the acetabulum.

Although some investigators prefer to examine both hips simultaneously and others prefer to examine each hip separately, the most important aspect of the hip examination is to focus closely on each hip during the examination. The Barlow and Ortolani tests detect hip instability with ligamentous laxity, and although they are valuable during the neonatal period, they usually become negative by 3 months of age (2).

Once the infant is 3 months of age, if the femoral head is subluxated or dislocated the adductor and flexor muscles gradually develop contractures. The most common physical finding in older infants with DDH is limited abduction of the hip (Fig. 4-5). The limited abduction may be subtle, so it is important that the infant is positioned supine on a firm table. An infant with bilateral DDH may have symmetrically limited abduction that can only be detected by a careful examination. If the DDH is unilateral, the superolateral subluxation or dislocation of the femoral head causes a limb-length discrepancy that may be detected by the family or primary care physician. The subluxation or dislocation shortens the thigh causing an increased number of thigh folds (telescoping) compared with the uninvolved side. Although asymmetric thigh folds may be a normal finding, it alerts the clinician to the possibility of DDH. If the hips are flexed to 90 degrees, the subtle limb-length discrepancy can be detected, as the knee on the side with DDH will be lower than the opposite side. This finding is termed a positive Galeazzi sign (Fig. 4-6). In this patient, the Ortolani maneuver is positive, so treatment with a Pavlik harness is recommended.

A 2-Year-Old Boy Is Referred for Evaluation of Bowed Legs, Intoeing, and Tripping Over His Feet. The family first noted that his legs were bowed at 3 months of age. When he began walking at 16 months of age, the bowing was worse and his feet turned in. His feet now turn in so much that he trips over them falling frequently. The birth history reveals that he was born after a 40-week gestation via normal vaginal delivery with a birth weight of 4000 g (8 lb 13 oz). His developmental milestones reveal that he first sat at 7 months of age and began walking at 16 months of age. The family history reveals that the father wore a brace until he was 2 years old because his feet turned in.

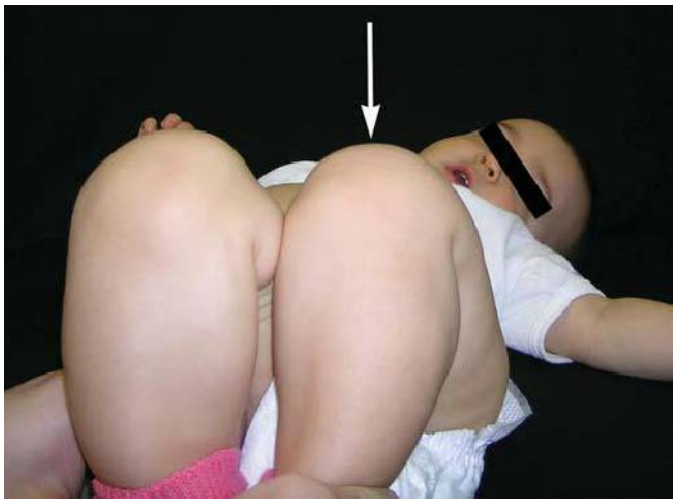

FIGURE 4-6. The subtle femoral-length discrepancy that is seen with the hips flexed to 90 degrees is termed a positive Galeazzi sign. The Galeazzi sign is seen in DDH when the knee on the side with DDH is lower than the opposite side (*arrow*).

TABLE 4-1 Average Developmental Achievement by Age

Age	Achievement
1 mo	Partial head control in prone position
2 mo	Good head control in prone position; partial head control in supine position
4 mo	Good head control in supine position; rolls over prone to supine
5 mo	Rolls over supine to prone
6 mo	When prone, lifts head and chest with weight on hands; sits with support
8 mo	Sits independently; reaches for toys
10 mo	Crawls; stands holding onto furniture
12 mo	Walks independently or with hand support
18 mo	Developing handedness
2 yr	Jumps; knows full name
3 yr	Goes upstairs alternating feet; stands momentarily on one foot; knows age and gender
4 yr	Hops on one foot; throws ball overhand
5 yr	Skips; dresses independently

Since most 2-year-old children fall frequently, the clinician focuses on certain aspects of the history and physical examination to determine if the child has developmental delay. If so, he may have problems with coordination or retention of primitive reflexes that should have already disappeared. If the bowed legs represent physiologic bowing, one would expect the deformity to be improving by 2 years of age. If the intoeing is physiologic and represents a normal rotational variation, it will usually be symmetric and is often not noticed until the child begins walking. A unilateral problem, involving the foot, may indicate a mild clubfoot or a neurologic problem such as a tethered spinal cord. The clinician reviews the developmental history as most children will sit independently by 6 to 9 months of age, cruise (walk around furniture) by 10 to 14 months of age, and walk independently by 8 to 18 months of age (Table 4-1).

If the child has developmental delay, it is important to verify the details surrounding the birth to determine if the child was born premature, or if there were any perinatal complications. Premature infants born after 25 to 30 weeks of gestation, with a birth weight of 750 g (1 lb 10 oz) to 1500 g (3 lb 5 oz), have an increased incidence of cerebral palsy with spastic diplegia. The first sign of this disorder may occur when the family notes that their child is delayed in walking, limping, or tripping over his feet. When evaluating for developmental delay, it is valuable to ask if the infant is ambidextrous. Most children will remain ambidextrous until 18 months to 3 years of age (Table 4-1). If a child who is tripping over his left foot is also strongly right-handed, the birth history may reveal an intrauterine cerebral vascular accident causing cerebral palsy with spastic left hemiplegia.

A 2-year-old boy may be apprehensive and uncomfortable in the exam room, so it may be helpful to begin the physical examination by opening the door and asking the family if they would like to take their son for a walk down the hall. Most 2-year-olds will enjoy walking away from the clinician and the exam room, but they often need to be carried back. While the family and child are walking down the hall, the clinician observes the child's gait pattern including the foot-progression angle (3). The foot-progression angle is the angle between the axis of the foot and an imaginary straight line on the floor (Fig. 4-7). The axis of the foot is derived from a line connecting a bisector of the heel with the center of the second metatarsal head. The foot-progression angle in children 1 to 4 years of age can vary from 15 degrees of inward to 25 degrees of outward rotation. The gait pattern can also vary considerably in this age group, but usually it will be relatively symmetric, with a similar amount of time being spent in stance phase (60% of the gait cycle) and swing phase (40% of the gait cycle). Rotational values within two standard deviations of the mean are termed "rotational variations," and values outside two standard deviations are termed "torsional deformities" (4).

The degree and location of any rotational variations can be documented by creating a rotational profile (Table 4-2). The rotational profile includes the foot-progression angle, internal and external rotation of the hips, the thigh-foot angle, and any foot deformities. The foot-progression angle measures the degree of intoeing or outtoeing compared with an imaginary straight line on the floor (normal range 15 degrees inward to 25 degrees outward rotation) (Fig. 4-7). The internal and external rotation of the hips measures the femoral rotational variation or torsion. Measuring internal rotation of the hips in the prone position is a very important test in pediatric orthopaedics because many hip disorders can be detected by this examination including toxic synovitis, Legg-Calvé-Perthes disease, slipped capital femoral epiphysis (SCFE), and septic

TABLE 4-2 Rotational Profile

Parameter	Right	Left
Foot-progression angle[a]	15 degrees	15 degrees
Hip internal rotation	70 degrees	70 degrees
Hip external rotation	30 degrees	30 degrees
Thigh-foot angle[a]	20 degrees	20 degrees
Sole of foot	Straight	Straight

The rotational profile includes the foot-progression angles, internal rotation of the hips, external rotation of the hips, the thigh-foot angles, and any foot deformities. The angles should be recorded in degrees, and the foot deformities should be described. The example shows that this child has internal femoral and internal tibial variations.

[a]For foot-progression angle and thigh-foot angle, a positive number indicates inward rotation and a negative number indicates lateral rotation.

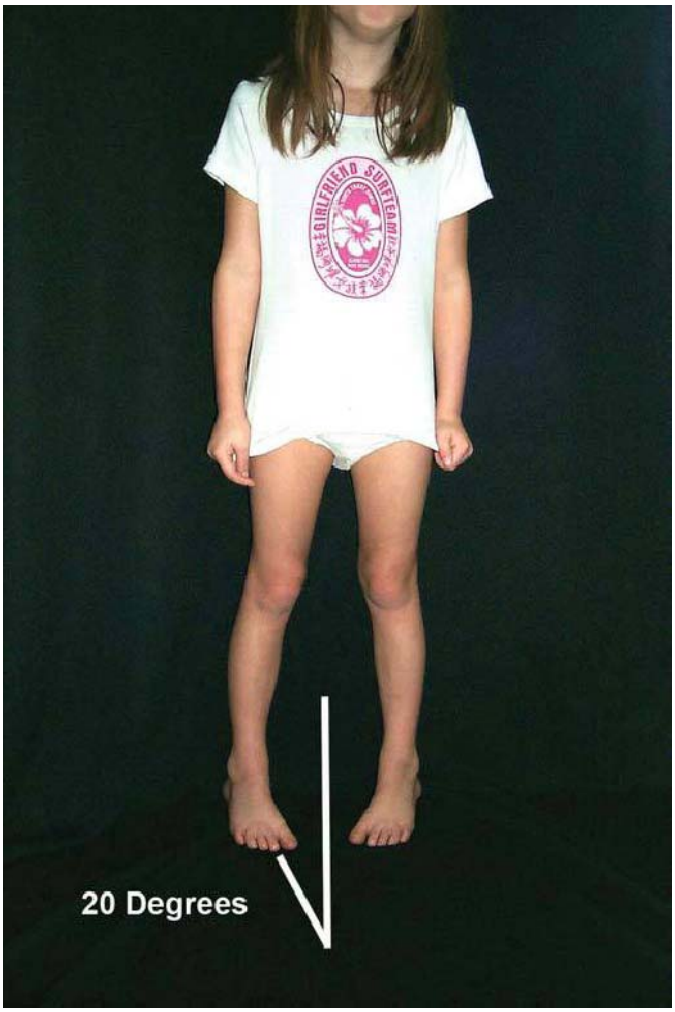

FIGURE 4-7. While the patient is walking, the foot-progression angle is the angle between the axis of the foot and an imaginary straight line on the floor representing the direction of movement. The axis of the foot is derived from a line connecting a bisector of the heel with the center of the second metatarsal head. This patient has a foot-progression angle of 20 degrees of internal rotation.

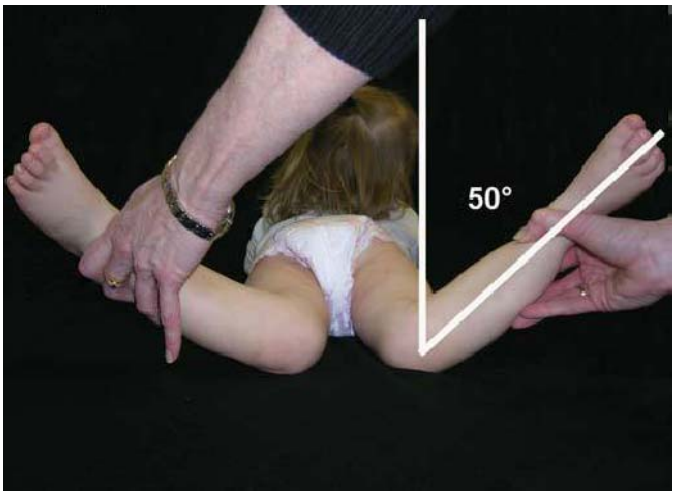

FIGURE 4-8. The internal rotation of the hips can be measured in the supine or prone position. Standing at the foot of the bed, with the patient prone, gravity allows the hips to fall into internal rotation. The angle between the leg and a line perpendicular to the tabletop measures the internal rotation (50 degrees in this patient).

arthritis (Fig. 4-8). The normal range of internal rotation is 20 to 80 degrees (Fig. 4-8), and the normal range of external rotation is 25 to 80 degrees (Fig. 4-9). The thigh-foot angle is the angle between the axis of the thigh and the axis of the foot, with the patient prone and the knee flexed 90 degrees (Fig. 4-10). The thigh-foot angle measures tibial rotational variation or torsion, and the normal ranges are 25 degrees of inward to 25 degrees of outward rotation (4). The foot examination documents any foot deformities that may be contributing to the intoeing. Once the profile is filled out, it gives an

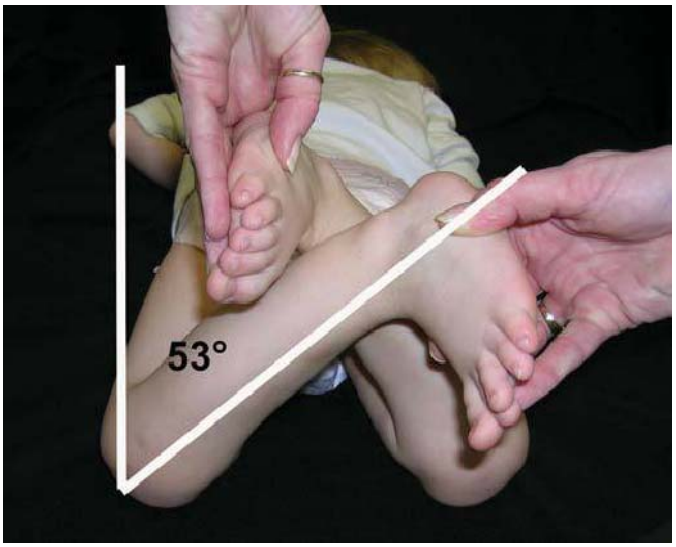

FIGURE 4-9. Standing at the foot of the bed, with the patient prone, gravity allows the hips to fall into external rotation. The angle between the leg and a line perpendicular to the tabletop measures the external rotation (53 degrees in this patient).

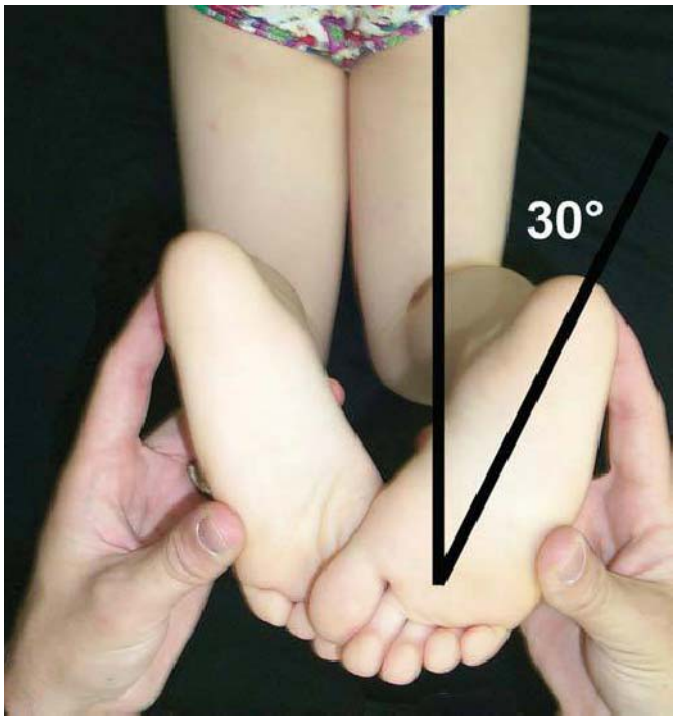

FIGURE 4-10. Standing at the foot of the bed, with the patient prone, the thigh-foot angle is the angle between the axis of the thigh and the axis of the foot, with the foot held in neutral position. The axis of the foot is derived from a line connecting a bisector of the heel with the center of the second metatarsal head. The thigh-foot angle measures the amount of tibial torsion (30 degrees in this patient).

objective view of the location and magnitude of any rotational variations or torsional deformities. This 2-year-old boy has internal rotational variations of both femurs and tibias. The rotational profile can be used as a baseline while following the child to document that rotational variations are indeed changing with growth.

In describing bowlegs and knock knees, the terms "varus" and "valgus" refer to the orientation of the distal fragment (leg) compared with the midline or proximal fragment (thigh). In a child with bowlegs, the distal fragment (tibia) is angulated toward the midline compared with the proximal fragment (femur) and is termed "genu varum." In a child with knock knees, the tibia is angulated away from the midline compared with the femur and is termed "genu valgum." In a child with bowlegs, when the ankles are touching, there is a gap between the knees, whereas in a child with knock knees, when the knees are touching there is a gap between the ankles. Most infants are born with bowlegs that spontaneously correct between 12 and 24 months of age. If the bowlegs correct by 2 years of age, it is termed physiologic bowing. The lower extremities then gradually develop genu valgum, which peaks between 3 and 4 years of age, then decreases to reach the normal adult tibiofemoral alignment of 7 degrees of genu valgum by 7 to 8 years of age (Fig. 4-11) (5).

On physical examination, the lower extremities are closely inspected to determine exactly where the deformity is located. If the deformity is mainly located in the proximal tibia, it may indicate tibia vara or Blount disease. If the deformity

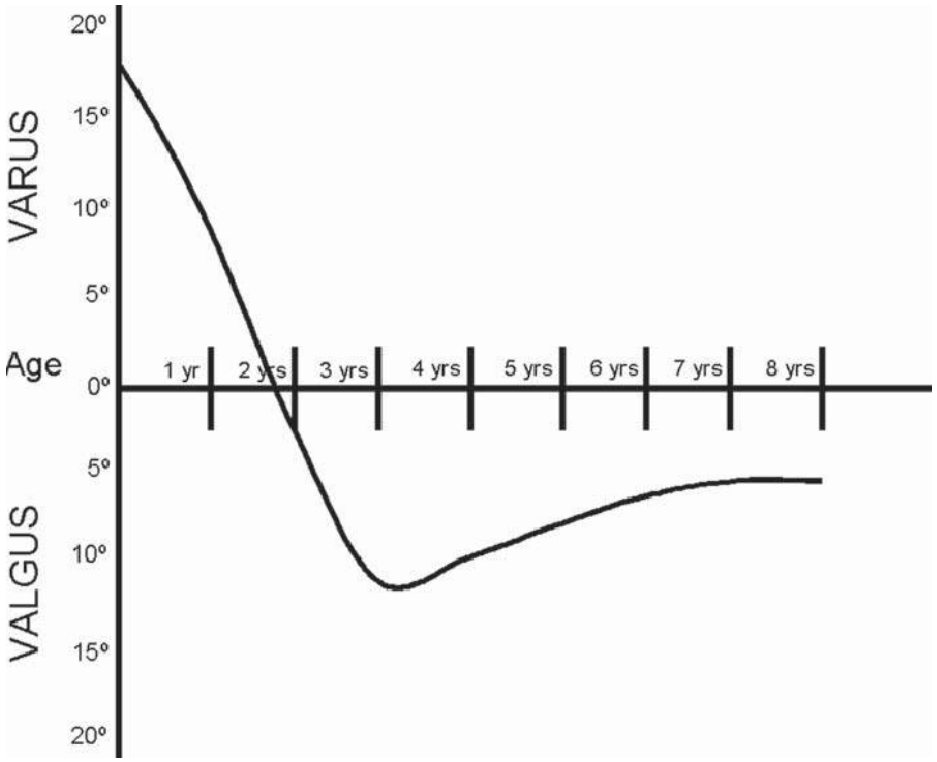

FIGURE 4-11. Graph demonstrating the development of the tibiofemoral angle. Infants have genu varum that typically corrects by 18 to 24 months of age. The lower extremities then gradually develop genu valgum, which peaks between 3 and 4 years of age. The genu valgum then decreases to reach the normal adult tibiofemoral alignment of 7 degrees of valgus by 7 to 8 years of age.

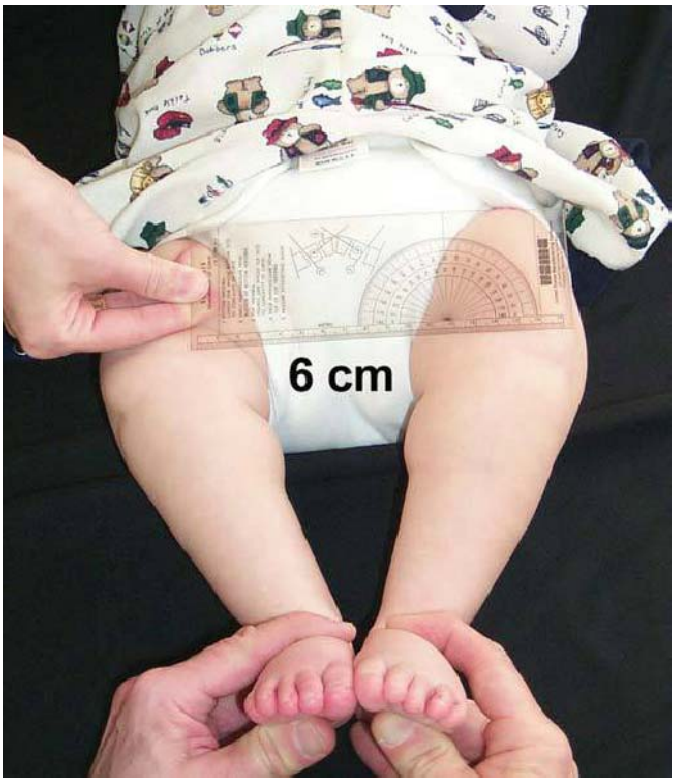

FIGURE 4-12. To measure the intercondylar distance, the child is supine with the lower extremities in extension. The feet are brought together until the medial malleoli just touch; the intercondylar distance is the distance between the femoral condyles (6 cm in this patient).

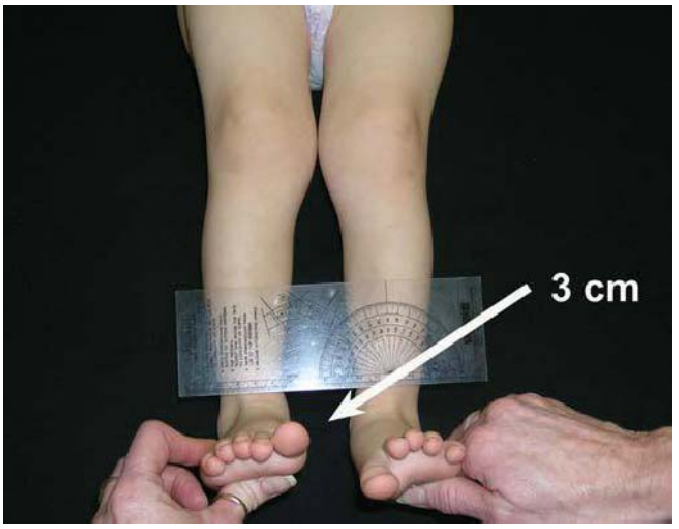

FIGURE 4-13. To measure the intermalleolar distance, the child is supine with the lower extremities in extension. The feet are brought together until the femoral condyles just touch; the intermalleolar distance is the distance between the medial malleoli (3 cm in this patient).

is symmetric, involving both the distal femur and proximal tibia, it may indicate physiologic bowing (6). The genu varum deformity is documented by measuring the "intercondylar distance." The intercondylar distance is measured in the supine position with the hips and knee in extension. The feet are brought together until the medial malleoli are just touching, and the intercondylar distance is the distance between the femoral condyles (Fig. 4-12).

A genu valgum deformity is documented in a similar fashion by measuring the "intermalleolar distance." With the child in the same position, the feet are brought together until the femoral condyles are just touching, and the intermalleolar distance is the distance between the medial malleoli (Fig. 4-13). This 2-year-old boy likely has physiologic bowing with internal tibial torsion, so the clinician anticipates that the intercondylar distance and thigh-foot angles will decrease over the next 6 months.

A Newborn Boy Is Referred for Evaluation of a Right Foot Deformity. A newborn boy was noted in the neonatal nursery to have a right foot deformity. The birth history reveals that he was the mother's first child. Routine ultrasound screening at 28 weeks of gestation revealed concern for a possible right clubfoot deformity. The pregnancy was otherwise uncomplicated, and the baby was born by spontaneous vaginal delivery at full term weighing 3500 g (7 lb and 11 oz). The family history reveals that a maternal uncle had multiple foot surgeries performed at a young age.

Foot deformities are commonly seen in newborn infants, with an incidence of approximately 4% (7). The most common foot deformity is metatarsus adductus with talipes equinovarus and vertical talus much less frequently seen. The physical examination of the foot can easily be performed with the baby lying supine of the examination table or on the parents lap if the child is fussy. The upper extremities, neck, spine, hips, and knees are all examined first and determined to be within normal limits. The foot is then visually inspected and found to have multiple deformities as well as abnormal creases. There is only a single heel crease as well as the presence of a deep medial plantar crease.

Palpation and physical examination of the foot reveals the forefoot is adducted (indicating metatarsus adductus), the arch is high (indicating pes cavus), and the hindfoot is rolled into varus and equinus (Fig. 4-14). The tibiotalar, subtalar, and calcaneocuboid joints are gently taken through a full range of motion and reveal decreased movement compared to the other side.

Metatarsus adductus is the most common foot deformity and may be a result of intrauterine positional deformity (Fig. 4-15). Metatarsus adductus has forefoot adductus, but unlike a clubfoot there is no hindfoot equinovarus deformity. It is associated with DDH and torticollis, highlighting the importance of a careful examination of face, neck, and hips (8). The forefoot alignment in relation to the hindfoot can be evaluated by the "heel bisector line" (9). This line is generated by drawing a line down the foot that is center over the calcaneus and parallel to its axis (Fig. 4-16). A normal heel bisector should intersect between the second and the third ray. The metatarsus adductus is mild if the line bisects the third ray, moderate if

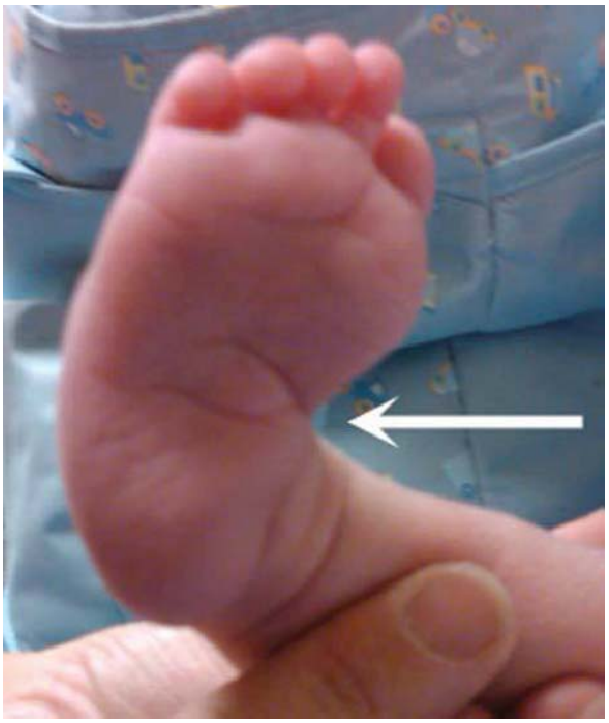

FIGURE 4-14. A clubfoot has forefoot adduction (metatarsus adductus), a high arch (pes cavus), and hindfoot varus and equinus. Depending on the severity of the deformity, a clubfoot may have a posterior and medial skin crease (*arrow*).

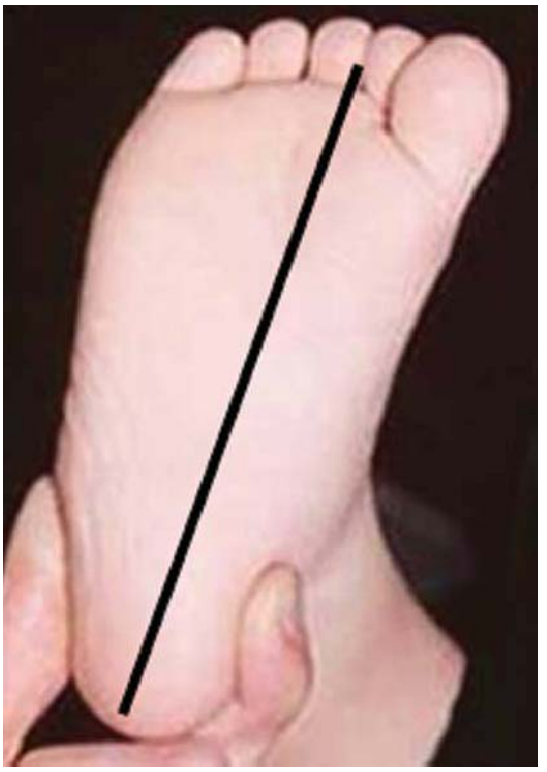

FIGURE 4-16. The normal heel bisector line intersects between the first and second rays.

it bisects the third and fourth rays, or severe if it bisects the fourth or the fifth ray. The lateral border of the foot is inspected and unlike a normal foot that has a straight lateral border, the lateral border is convex or bean shaped indicating metatarsus adductus. A foot that only has metatarsus adductus will have a neutral hindfoot, whereas a clubfoot will have an equinovarus hindfoot deformity. The flexibility of the metatarsus adductus can be assessed by placing the thumb of one hand on the calcaneocuboid joint laterally and grasping the medial forefoot with the other and passively abducting the forefoot (Fig. 4-17). If the metatarsus adductus can be corrected beyond the neutral axis, it is considered flexible. If the metatarsus adductus does not correct beyond the neutral axis, it is considered rigid.

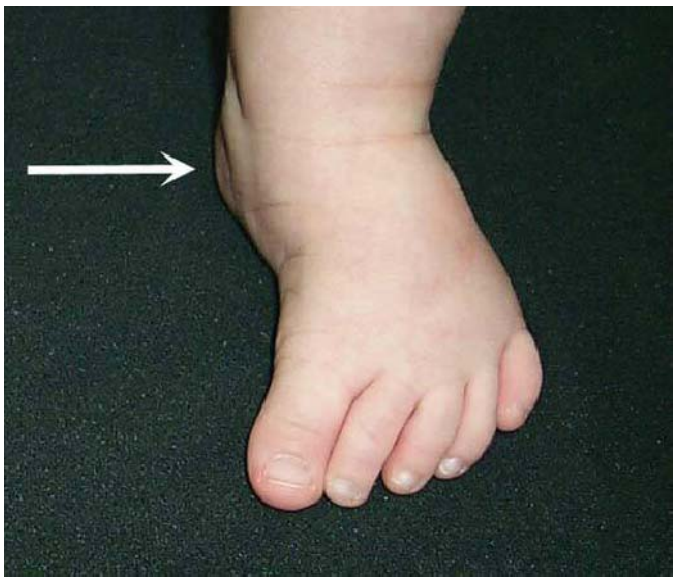

FIGURE 4-15. Metatarsus has forefoot adduction, but unlike a clubfoot the hindfoot is in neutral alignment (*arrow*).

Talipes equinovarus or a clubfoot presents as a spectrum of deformity characterized by midfoot cavus, forefoot adductus, and hindfoot varus and equinus (CAVE). Inspection of the skin of a clubfoot reveals varying degrees of posterior and medial skin creases depending on the severity of the deformity (Fig. 4-14). The hindfoot is palpated to evaluate the position of the calcaneus. When the calcaneus is markedly plantarflexed (equinus), the heel pad is displaced and appears absent. This phenomenon is termed an "empty heel pad sign." In a congenital clubfoot deformity, both the foot and calf are typically smaller than the normal side. In addition, the thigh-foot angles (Fig. 4-10) typically reveal internal tibial torsion and a shortened tibia on the side with the clubfoot (10).

The foot is then examined to assess the rigidity of the deformity by gently attempting to correct the midfoot cavus, forefoot adductus, and hindfoot varus and equinus. The most frequently used classification system to objectively quantify clubfoot rigidity is the Dimeglio clubfoot score (11). A clubfoot can also be classified as typical or atypical. A typical clubfoot is the classic clubfoot that is found most often in otherwise normal infants. An atypical clubfoot is often seen in association

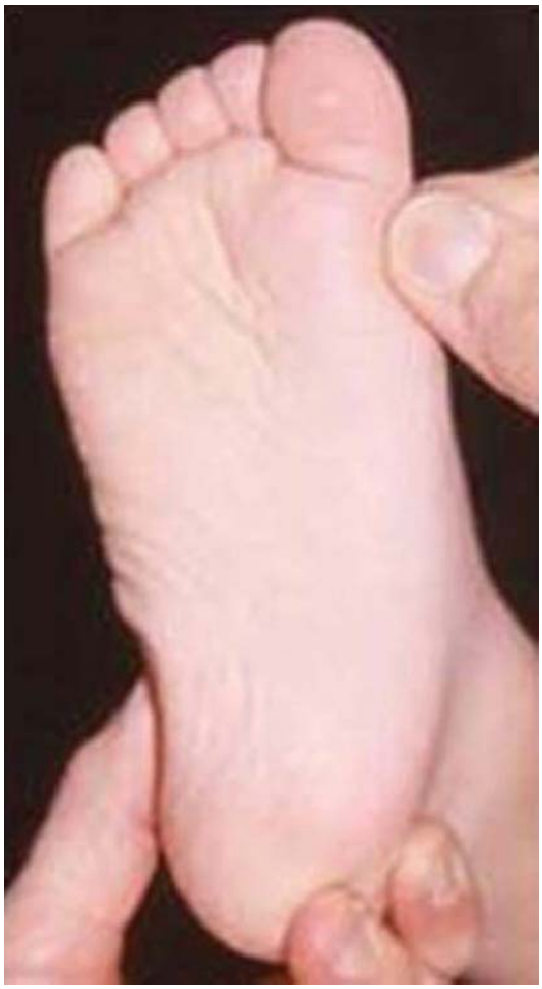

FIGURE 4-17. The flexibility of the metatarsus adductus can be assessed by placing the thumb of one hand on the calcaneocuboid joint laterally and abducting the forefoot with the other hand. If the metatarsus adductus corrects beyond the neutral axis, it is classified as flexible; if the metatarsus adductus does not correct beyond the neutral axis, it is classified as rigid.

with other neuromuscular disorders, such as arthrogryposis and myelomeningocele, and is usually less responsive to nonoperative management. The atypical clubfoot can be thin or fat and are frequently stiff, short, and chubby and with a deep crease on the plantar surface of the foot and behind the ankle. They may have shortening of the first metatarsal with hyperextension of the metatarsophalangeal joint reflecting a plantarflexed first ray.

A congenital clubfoot deformity is easily differentiated from congenital vertical talus (CVT) even though hindfoot equinus is prominent in both disorders. As opposed to the clubfoot that is typically seen in otherwise normal children, CVT is often associated with neuromuscular disorders including myelomeningocele, arthrogryposis multiplex congenital, spinal muscular atrophy, and prune-belly syndrome. On examination, in contrast to the clubfoot that has forefoot adductus and hindfoot varus, the CVT foot has forefoot abductus and hindfoot valgus, often described as a "rocker bottom foot." The talar head is palpable on the plantar surface of the foot and creates the apex of the convex plantar surface (Fig. 4-18). In a CVT, the medial border of the foot is convex or bean shaped, whereas in a clubfoot the lateral border of the foot is convex or bean shaped.

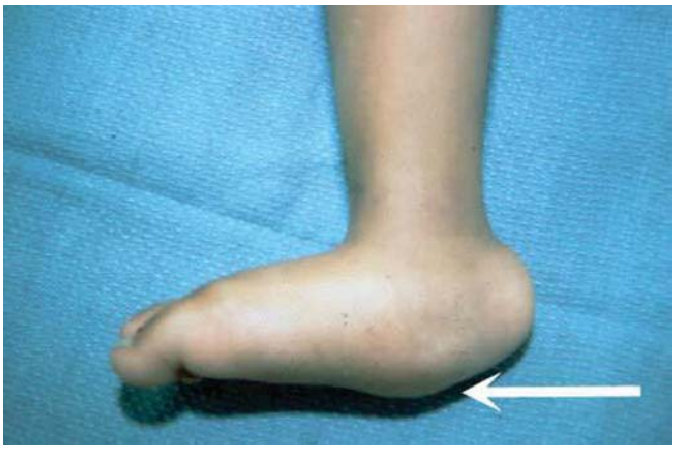

FIGURE 4-18. CVT has forefoot abduction and hindfoot equinovalgus, often described as a "rocker bottom foot." The talar head is palpable on the plantar surface of the foot (*arrow*).

This boy has a typical right congenital idiopathic clubfoot deformity. The clinician discusses the natural history of the congenital clubfoot deformity as well as the current treatment and recommends that stretching and treatment should begin preferably within the next few weeks.

An 18-Month-Old Boy Is Referred for Developmental Delay and Inability to Walk. The family first suspected a problem when he was 4 months old and was still having difficulty holding his head up. They became more concerned when he was not sitting at 10 months of age. He finally began sitting independently at 14 months of age and he just recently began pulling to standing, but is not yet cruising are the furniture. He was born after a 28-week gestation, with a birth weight of 1100 g (2 lb 7 oz). He had perinatal respiratory difficulties and was hospitalized in the NICU for 2 months. He developed a seizure disorder at 1 year of age, and his seizures are now under good control with medication.

This patient has developmental delay so the standard physical examination will also include a detailed neurologic examination and developmental assessment. An 18-month-old boy with developmental delay will usually not be apprehensive, and it is convenient to begin the physical examination with the boy in the supine position. The clinician grasps his hands, gradually pulling him into the sitting position, while looking for head and trunk control. A child will usually have head control by 2 to 4 months of age and trunk control by 6 to 8 months of age (Table 4-1). In children, there are a series of primitive reflexes, including the Moro, grasp, neck-righting, symmetric tonic neck, and asymmetric tonic neck reflexes, which are present at birth and then gradually disappear with

TABLE 4-3 Primitive and Postural Reflexes

Reflex	Age When It Disappears
Primitive reflex	
Moro	6 mo
Grasp	3 mo
Neck righting	10 mo
Symmetric tonic neck	6 mo
Asymmetric tonic neck	6 mo
Postural reflex	
Foot placement	Early infancy
Parachute	12 mo

normal development by 3 to 10 months of age (Table 4-3). If these reflexes persist beyond 10 months of age, it may be a sign of a neuromuscular disorder.

The Moro reflex is elicited by introducing a sudden extension of the neck. The sudden neck extension causes the reflex where the shoulders abduct and the upper limbs extend, with spreading of the fingers, followed by an embrace (Fig. 4-19). The Moro reflex usually disappears by 6 months of age (12). The grasp reflex is elicited by placing a finger in the infant's palm from the ulnar side. The infant's fingers will firmly grasp the clinician's finger. If traction is applied to the hand, the grasp reflex is so strong that the clinician can lift the infant's shoulder off the table (Fig. 4-20). The grasp reflex usually disappears by 3 months of age. The neck-righting reflex is elicited by turning the head to one side; it is positive if the trunk and limbs spontaneously turn toward the same side. This reflex usually disappears by 10 months of age. The symmetric tonic neck reflex is elicited by flexion of the neck, which causes flexion of the upper limbs and extension of the lower limbs. Similarly, extension of the neck causes extension of the upper limbs and flexion of the lower limbs. The asymmetric tonic neck reflex is elicited by turning the head to the side, which causes extension of the upper and lower extremities on the side toward which the head is turned, and flexion of the upper and lower extremities on the opposite side. This position is termed the "fencing position." The symmetric and asymmetric tonic neck reflexes usually disappear by 6 months of age.

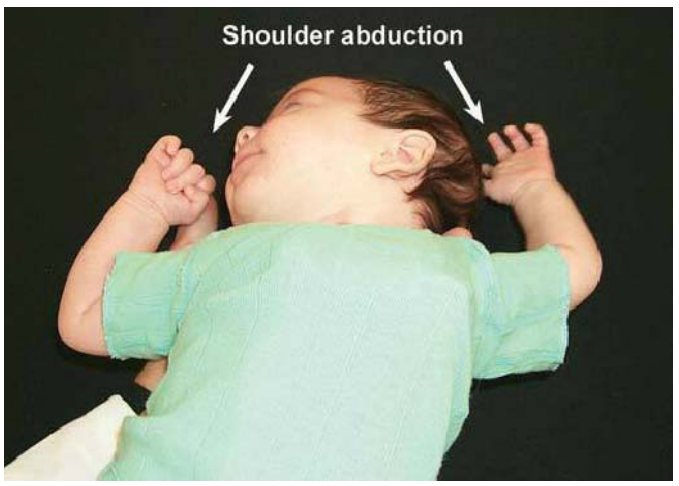

FIGURE 4-19. The Moro reflex is elicited by gently lifting the infant with the right hand under the upper thoracic spine and the left hand under the head. The left hand is dropped to allow sudden neck extension. The infant abducts the upper limbs, with spreading of the fingers, followed by an embrace.

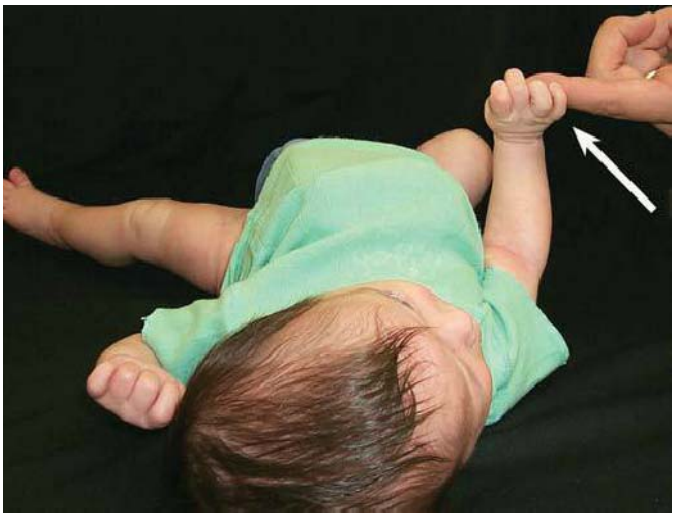

FIGURE 4-20. The grasp reflex is elicited by placing a finger in the infant's palm from the ulnar side (*arrow*). The infant's fingers will firmly grasp the finger and if traction is applied to the hand, the grasp reflex is stronger.

The extensor thrust, an abnormal reflex, is elicited by holding the infant under the arms and touching the feet to the floor, which causes a rapid extension of all of the joints of the lower limb, progressing from the feet to the trunk. A normal infant will flex rather than extend the joints of the lower extremities when placed in this position. These primitive reflexes need to resolve with growth and development before the child will be able to walk independently.

There are other primitive reflexes that gradually disappear in normal children at different stages of development, including the rooting, startle, Gallant, and Landau reflexes. The rooting reflex is elicited by touching the corner of the mouth, which causes the mouth and tongue to turn toward the side that was stimulated. The startle reflex is elicited by making a loud noise, which causes a mass myoclonic response resembling a Moro reflex, except that the elbows remain flexed. The startle reflex may persist into adulthood. The Gallant reflex is elicited by stroking the side of the trunk, which causes the infant to bend the spine toward the side that was stimulated, creating a scoliosis convex to the opposite side that was stimulated. The Landau reflex is elicited by supporting the infant by the trunk in the horizontal prone position; the typical response is extension of the neck, spine, and extremities. If the infant collapses into an upside-down U, it may indicate hypotonia.

There is another group of reflexes (postural reflexes) that gradually appear with normal development of the nervous system, including the parachute reflex and the foot-placement reaction (Table 4-3). The parachute reflex is elicited by holding the infant in the air in the prone position, then suddenly lowering the infant headfirst toward the table, simulating a fall (Fig. 4-21). The reflex is positive if the infant extends the upper extremities to break the fall. This reflex usually appears by 12 months of age and remains into adulthood. The foot-placement reaction is elicited by holding the infant under the arms, then gently lifting the infant so that the dorsum of the foot or the anterior surface of the tibia touches the side of the table. It is positive if the infant picks up the extremity and steps up onto the table (Figs. 4-22). The foot-placement reaction usually develops early in infancy and may persist until the age of 3 or 4 years.

Bleck (12) evaluated 73 children who were 12 months of age or older and were still not yet walking to determine their prognosis for walking. He used seven tests to predict if an infant would subsequently walk. One point was assigned for each primitive reflex that was still present, and one point was assigned for each postural reflex that was still absent (Table 4-4). A score of two points or more indicated a poor prognosis for walking, a one-point score indicated a guarded prognosis, and a zero-point score indicated a good prognosis.

The physical examination continues by evaluating the spine for any scoliosis or kyphosis. The upper and lower extremities are examined to assess range of motion and to document any contractures. If a contracture is identified, the clinician attempts to passively correct it to determine if it is flexible or rigid. An 18-month-old boy with cerebral palsy and spastic diplegia will typically have contractures that can be passively corrected, whereas a similar child with cerebral palsy and spastic quadriplegia may have already developed rigid contractures. When the clinician gradually attempts to passively correct a rigid contracture, if the contracture has continuous resistance to passive correction, it is termed "lead-pipe rigidity." If the contracture has discontinuous resistance to passive correction, it is termed "cog-wheel rigidity" (12). A patient with cerebral palsy and athetosis may have purposeless

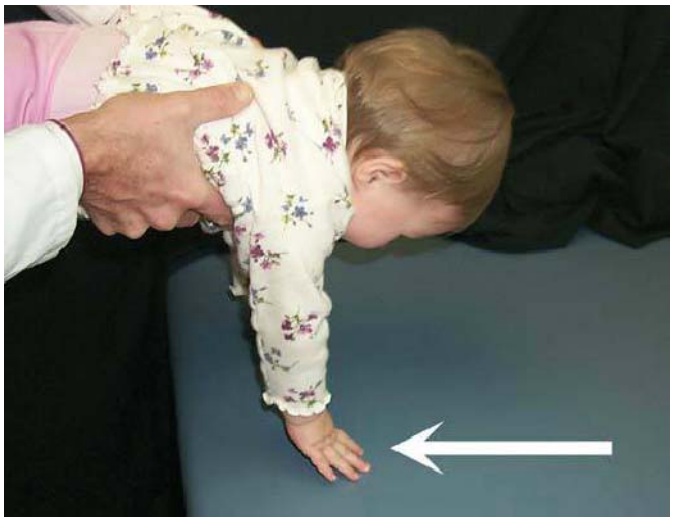

FIGURE 4-21. The parachute reflex is elicited by holding the infant in the air in the prone position, then suddenly lowering the infant headfirst toward the table, simulating a fall. The reflex is positive if the infant extends the upper extremities as if to break the fall (*arrow*).

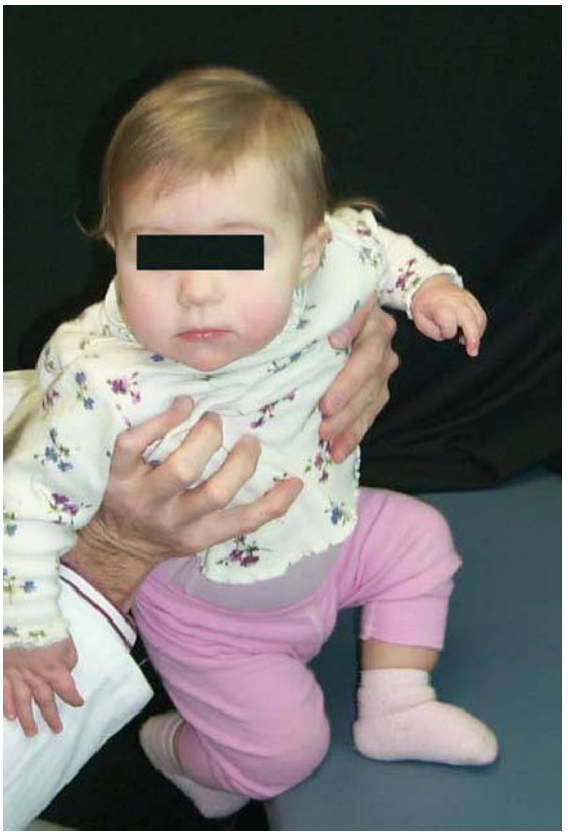

FIGURE 4-22. The foot-placement reaction is elicited by gently lifting the infant so that the dorsum of the foot or the anterior surface of the tibia touches the side of the table. It is positive if the infant picks up the extremity and steps up onto the table.

TABLE 4-4 Prognosis for Walking

Reflex	Points
Primitive reflex	
Asymmetric tonic neck	1
Neck righting	1
Moro	1
Symmetric tonic neck	1
Extensor thrust	1
Postural reflex	
Parachute	1 if absent
Foot placement	1 if absent

Prognosis for walking: 2 points, poor; 1 point, guarded (might walk); 0 points, good.

type movement patterns, particularly involving the hands and upper extremities. If the athetosis is of the tension type, it can often be "shaken out" of the limb by the clinician. The reflexes are also tested to determine if the patient has hyperreflexia, clonus, and a positive Babinski reflex. This boy has cerebral palsy with spastic diplegia.

A 3-Month-Old Boy Is Referred for Evaluation Because He Is Not Moving His Right Arm. Shortly after delivering a healthy 5250 g (11 lb 9 oz) baby boy, the mother was told that the baby was not moving his right arm. The pregnancy was normal, but the delivery was difficult because of right shoulder dystocia. The delivery team had to apply considerable traction on the head to deliver the baby. They noted some swelling and tenderness on the right side of the baby's neck shortly after birth, but this resolved in the first week. At the 2-month appointment with the pediatrician, he was moving his hand but always kept the upper extremity at his side.

After a pediatric orthopaedic history and physical examination, the clinician focuses on a detailed examination of the upper extremities, comparing the paralyzed right side with the uninvolved side. It is important to distinguish between a brachial plexus palsy (a traumatic paralysis involving the upper extremity) and a pseudoparalysis secondary to osteomyelitis of the proximal humerus, septic arthritis of the shoulder, or a birth fracture. The treatment for each of these conditions is different, and a delay in treatment of osteomyelitis or septic arthritis can be devastating. An infant with osteomyelitis, septic arthritis, or a birth fracture will usually have swelling at the site, whereas an infant with traumatic brachial plexus palsy will have no swelling in the extremity, but may have swelling in the neck. An infant with a brachial plexus birth palsy or birth fracture of the humerus will usually have paralysis at birth, whereas an infant with osteomyelitis or septic arthritis may be normal after birth, and then suddenly develop the pseudoparalysis.

Traumatic brachial plexus palsy is a common birth injury, typically seen in primigravida mothers with large babies after difficult deliveries. It occurs because of traction and lateral tilting of the head to deliver the shoulder. If the baby is in the breech presentation, it occurs because of traction and lateral tilting of the trunk and shoulders to deliver the head. Traumatic brachial plexus palsy may have an associated fracture of the clavicle or humerus. There are three types of brachial plexus palsies, depending on which part of the brachial plexus is affected.

The Erb palsy affects the upper roots (C5–C6), the Klumpke palsy affects the lower roots (C8 and T1), and total plexus palsy affects all of the roots in the brachial plexus. The Erb type is the most common and the Klumpke type is rare in newborns. The prognosis for recovery depends on the level and magnitude of the injury and the time at which certain key muscles recover function. If the biceps recovers function before 3 months of age, the prognosis is excellent for a full recovery. The presence of a Horner syndrome usually indicates a poor prognosis (13).

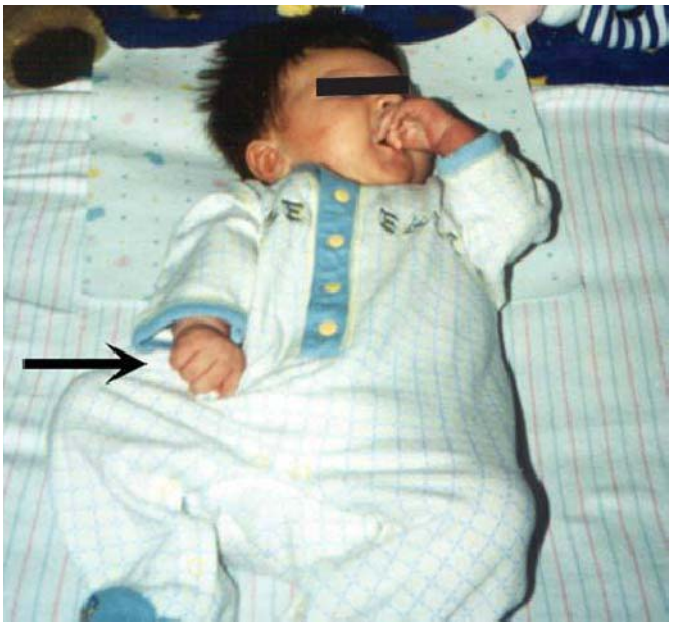

FIGURE 4-23. Paralysis of C5 and C6 causes the shoulder to be held in adduction and internal rotation, with the elbow in extension, the forearm in pronation, and the wrist and fingers in flexion. This posture is termed the waiter's tip, as if the infant is cleverly asking for a tip (*arrow*).

On physical examination, an infant with upper brachial plexus palsy is easily recognized by the absence of active motion of the involved extremity in the Moro reflex (Fig. 4-19), or the asymmetric tonic neck reflex. The paralysis of C5 and C6 causes the shoulder to be held in adduction and internal rotation, with the elbow in extension, the forearm in pronation, and the wrist and fingers in flexion. This posture is termed the "waiter's tip" as if the infant is cleverly asking for a tip (Fig. 4-23). This posture is not seen in an infant with osteomyelitis, septic arthritis, or birth fracture.

An infant with a lower brachial plexus palsy or total brachial plexus palsy is recognized by an absence of the grasp reflex in the involved extremity (Fig. 4-20). The hand is flaccid, with little or no voluntary control. When there is total plexus involvement and the entire extremity is flaccid, the Moro (Fig. 4-19) and grasp (Fig. 4-20) reflexes are both absent. A Horner syndrome refers to the constellation of signs resulting from the interruption of sympathetic innervations to the eye and ocular adnexae. The clinical findings include a triad of ipsilateral blepharoptosis, pupillary miosis, and facial anhidrosis. If the infant has a Horner syndrome, the prognosis for spontaneously recovery is decreased.

This 3-month-old boy is already starting to show biceps motor function at 3 months of age, so the prognosis for recovery is good.

An 18-Month-Old Boy Is Referred Because He Refuses to Walk After His Mother Fell While Carrying Him. The mother states that she was carrying her son on her hip when she twisted her foot and fell going

down the stairs. She was fine but her son immediately began crying and refused to walk. When she tried to stand him up, he would not put any weight on his right lower extremity. She believes that when she fell, she may have landed on his right leg. She has not noticed any swelling and he stopped crying after she gave him some anti-inflammatory medication. He is in good health and he has not had any chills or fever. She is a single mother with four other children. She called the pediatrician who evaluated him and recommended a radiograph. The radiograph showed a fractured tibia so he referred them for evaluation and treatment.

A minimally displaced spiral fracture involving the distal tibia in a toddler between 9 months and 3 years of age is termed a "toddler's fracture." Although toddler's fractures are relatively common, it is important to review the details concerning the history, physical examination, and radiographs to rule out nonaccidental trauma or "battered-child syndrome." Although children have been harmed by their caregivers for centuries, the medical profession did not officially acknowledge the battered-child syndrome until 1962 (14). The age of the boy is important because most child abuse involves children younger than 3 years of age. It has been estimated that 10% of cases of trauma seen in emergency departments in children under 3 years old are nonaccidental (15). Although a number of risk factors have been identified, it is important to remember that children of all socioeconomic statuses, backgrounds, and ages can be victims of abuse.

The clinician spends time in a quiet environment talking with the mother about the details surrounding the injury to determine if the history is consistent with the child's physical findings. If the history is not consistent with the physical findings, it may cause the clinician to suspect child abuse. While going over the details of the injury, the clinician closely observes the mother's demeanor to determine if she is being forthright with her answers. If the mother seems nervous or uneasy in describing the circumstances surrounding the accident, it should raise a red flag alerting the clinician that someone may have deliberately harmed the child. After reviewing the details of the mechanism of injury, the clinician reviews the past medical history to determine if this is her son's first fracture. A history of multiple previous fractures may be consistent with battered-child syndrome or osteogenesis imperfecta. The birth and developmental history are reviewed to determine if there is any underlying disorder that may make this child more susceptible to fracture. The clinician reviews the family history, review of systems, and personal and social history to evaluate for any family issues and to get a better feel for the home environment.

To check that the history is accurate and further evaluate the home environment, the clinician interviews other family members about the injury. It is important to rule out battered-child syndrome because if missed, there is possibility that the child will be injured again, and the next injury could be life threatening. Each year, more than 1 million children in the United States sustain injuries that are inflicted by their caregivers.

In this case, the physical examination includes the whole child, as the clinician is looking for other injuries that may indicate a battered-child syndrome. The height and weight are recorded to determine if there is any evidence of growth retardation or failure to thrive (16). The skin is closely inspected for any contusions, echymoses, abrasions, welts, or burn scars. Skin lesions are the most common presentation of physical abuse and may be the only physical finding. Bruises are common over the shins and knees in 18-month-old boys, but bruises over the buttocks or genitalia should raise a red flag. The head, eyes, ears, nose, and throat are closely examined for bruises or contusions. Head trauma is the most frequent cause of morbidity and mortality in abused children.

After the skin is inspected, the soft tissues and bones of the upper and lower extremities are palpated to evaluate for injuries. An 18-month-old boy should not have any discomfort when the clinician gently squeezes his arms, forearms, thighs, and legs, but will have considerable discomfort if there is a contusion or fracture. After skin lesions, fractures are the second most common presentation of physical abuse. If the clinician believes there is any question about the possibility of battered-child syndrome, it may be beneficial to contact the referring pediatrician to determine if any question of neglect has ever previously been considered. If the story is straightforward and the mother is forthcoming, treatment of the tibia fracture can proceed without any further studies.

A 4-Year-Old Boy Is Referred Because He Began Limping Yesterday and When He Awoke This Morning, He Refused to Walk on His Right Lower Extremity. He was apparently in good health until yesterday afternoon, when his mother noticed that he seemed to be limping on the right side at the grocery store. Later that evening, his limp became more obvious and he complained of pain in his right knee. This morning he awoke complaining of right knee pain and refused to walk. They called their pediatrician who evaluated him and referred him for a possible infection in the right knee. The past history reveals that 2 weeks ago he had a fever and cough that lasted for 5 days.

The clinician understands that although the history is typical for a patient with transient synovitis of the hip, it may also be consistent with septic arthritis, osteomyelitis, or Legg-Calvé-Perthes disease. A 4-year-old boy will often describe exactly where it hurts and may point to the groin, thigh, or the knee. It is important to remember that pain can be referred, and a hip problem presenting as knee pain is a classic example of referred pain. The clinician asks if the pain is constant or intermittent as children with infections tend to have constant pain. The fever and cough 2 weeks ago is an important part of the history, as an upper respiratory infection is often a precursor of transient synovitis of the hip.

Kocher et al. (17) compared a group of patients with transient synovitis with a group of patients with septic arthritis. They reported that the patients with septic arthritis appeared to be sicker with fever, chills, inability to bear weight, elevated erythrocyte sedimentation rate, leukocytosis, lower hematocrit,

and an altered peripheral blood differential. A patient with acute septic arthritis involving the hip would typically have a history of 1 to 2 days of severe pain, whereas a patient with juvenile arthritis may have had intermittent low-grade pain for several weeks to months. The pain associated with juvenile arthritis is typically worse in the morning, and this is not usually seen in other disorders. If the history revealed he had chicken pox 2 weeks ago, the clinician may be concerned the he is immunocompromised and may have an infection.

The physical examination can start by asking if the patient will stand and take a few steps. If he will walk, the gait pattern is observed to determine if it is symmetric. If the child has an antalgic (painful) gait on the right side, the stance phase of gait would typically be shortened and he would lean over the painful hip. Although it may be difficult to convince a 4-year-old boy to stand, particularly if he has pain, if he will corporate, he is asked to stand on one leg and then on the opposite leg. When a child stands on one leg, the hip abductor muscles contract to hold the pelvis up on the opposite side and avoid falling. The combination of weight-bearing and contracted abductor muscles markedly increases the joint reactive forces in the hip. If the patient has hip pain, the increased joint reactive forces caused by standing on one leg are so painful that he will not contract the hip abductor muscles. This causes the pelvis to drop on the opposite side and is termed a positive Trendelenburg test (Fig. 4-24).

Since the child is having pain, the uninvolved side is examined first before proceeding to the symptomatic side. The lower extremities are observed for any swelling or asymmetry. The clinician palpates the spine, pelvis, and lower extremities for tenderness. The hips are examined with the child in the supine position, and the clinician looks for any asymmetry as the hips are attempted to be taken through a full range of motion. The range of motion of both hips, especially internal rotation, should be symmetric. If the patient has an irritable hip, he will guard and contract his muscles, not allowing the clinician to take the hip through a full range of motion. This is particularly noted in attempting to internally and externally rotate the hip, with the hip and knee in 90 degrees of flexion. If the hip is painful, the clinician can gently "log roll" the extremity with the hip and knee in full extension (Fig. 4-25). This is more comfortable for the patient, and if he has severe pain with log rolling, the pain will be unbearable with the hip and knee in flexion. If there is any question about the possibility of a septic hip, urgent hip aspiration under fluoroscopic guidance is recommended.

After examining the hip, the limb can then be placed in the figure-4 position, with the hip in flexion, abduction, and external rotation (FABER test) (Fig. 4-26). In this position, if the knee is pushed toward the examining table, it transmits a tensile force to the sacroiliac joint. If the patient has pyogenic arthritis involving the sacroiliac joint, he will experience discomfort with this test. This boy has transient synovitis of the right hip, so activity modification and close follow-up are recommended to be certain that the symptoms are resolving.

FIGURE 4-24. The clinician palpates the iliac crests while the patient stands on the left lower extremity. In single limb support on the left lower extremity, the right iliac crest should rise as the left hip abductor muscles contract to support the pelvis. If the right iliac crest drops (*arrow*), it is termed a positive Trendelenburg test, indicating weakness of the left hip abductor muscles. The Trendelenburg test can also be positive if the patient has an irritable left hip. In this case, the increased joint reactive forces are painful, so the patient will not contract the left hip abductor muscles.

A 3-Year-Old Girl Is Referred for Evaluation of Flat Feet. The family states that her feet roll in when she walks. The problem was first noted by the maternal grandmother when she began walking at 13 months of age. The family is concerned that the problem is getting worse and they want to know if she should have arch supports or special shoes. The past medical history as well as the birth and developmental history are within normal limits. The family history reveals that her father had flat feet and wore special shoes until he was 2 years old.

The clinician reviews the details of the history to determine when the flat feet were first noted. This information may be helpful because a rigid pes planus deformity, such as that seen in a child with a CVT, is typically noted at birth. In contrast, a rigid pes planus deformity, such as that seen in a child with a tarsal coalition, is typically not noted until the child is 10 years of age, when the cartilaginous bar begins to ossify causing pain and decreased motion of the foot. A flexible

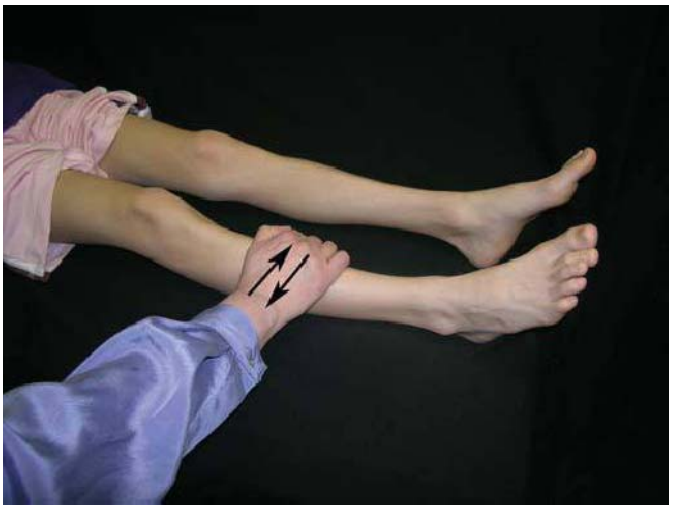

FIGURE 4-25. The clinician can gently "log roll" the extremity with the hip and knee in full extension to determine the severity of the pain. This is more comfortable for the patient and if he has severe pain with log rolling, the pain will be unbearable with the hip and knee in flexion.

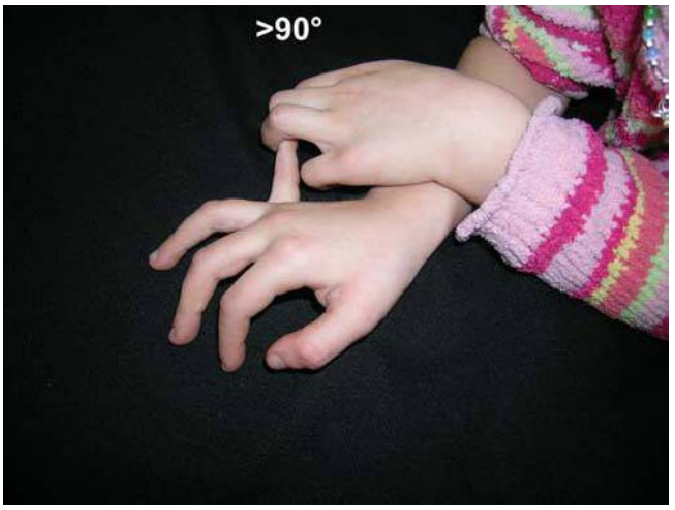

FIGURE 4-27. Ligamentous laxity can be detected by asking the patient to try and hyperextend the little finger metacarpophalangeal joint (>90 degrees indicates laxity).

pes planus deformity collapses with weight bearing, so it is not unusual that the flat feet were first noted when she first began walking. A 3-year-old girl with flexible flat feet will not usually have any pain.

The physical examination begins by opening the door and asking the family if they would take her for a walk in the hall. The clinician notes that she walks with a symmetric heel-toe gait pattern, with a foot-progression angle of 25 degrees of external rotation (Fig. 4-7). A patient with a planovalgus deformity will often toe-out, whereas a patient with a cavovarus deformity will often toe-in. Before focusing on the feet, a general physical examination of the back, upper, and lower extremities is performed. A patient with flexible pes planovalgus will often have generalized ligamentous laxity. Ligamentous laxity can be detected by asking the patient to hyperextend the little finger metacarpophalangeal joint (>90 degrees indicates ligamentous laxity, Fig. 4-27), hyperextend the elbows, hyperextend the knees, and touch the thumb to the volar surface of the forearm (Fig. 4-28). Flexible pes planus is common and is most likely caused by excessive laxity of the ligaments and joint capsules, allowing the tarsal arch to collapse with weight bearing. It is important to differentiate this benign condition

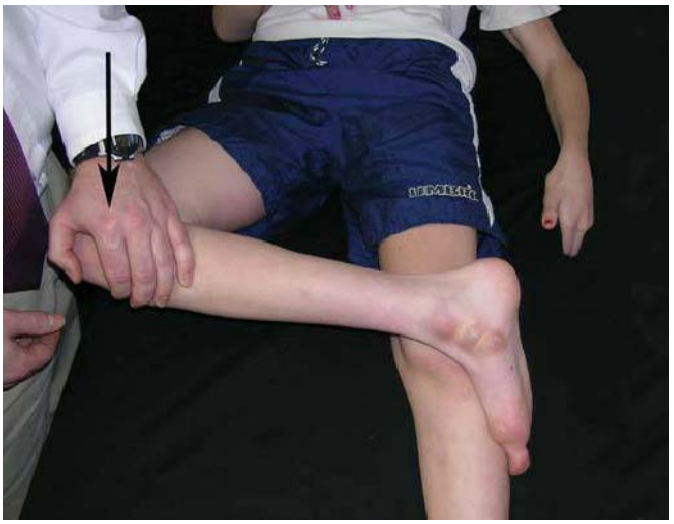

FIGURE 4-26. With the patient supine, the right lower extremity is placed in the figure-4 position with the hip in flexion, abduction, and external rotation (FABER test). The knee is gently pushed toward the examination table (*arrow*) transmitting a tensile force to the sacroiliac joint that may cause pain if the sacroiliac joint is inflamed.

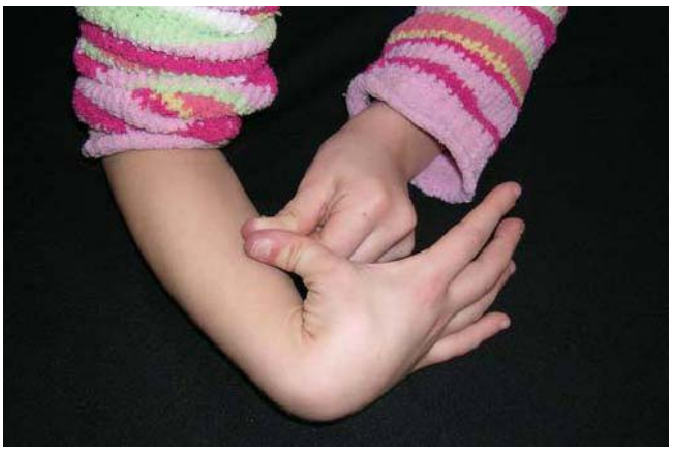

FIGURE 4-28. Ligamentous laxity can be detected by asking the patient to try and touch the thumb to the volar surface of the forearm.

from the more serious types of flat feet, such as CVT or tarsal coalition.

The clinician examines the range of motion of the ankle, subtalar, and tarsal joints to determine if there is any loss of motion. A contracture of the Achilles tendon may accompany a symptomatic flat foot (18). To determine if she has a contracture of the Achilles tendon, it is crucial to supinate the forefoot and lock the subtalar and tarsal joints before attempting to passively dorsiflex the foot and ankle to test for a contracture of the Achilles tendon. If the foot is not first supinated, passive dorsiflexion may occur at the subtalar and tarsal joints rather than the ankle, masking the contracture of the Achilles tendon. In standing, a child with flexible pes planus has a collapsed medial longitudinal arch, a valgus hindfoot, and a supinated externally rotated forefoot (Fig. 4-29A). The arch returns when the child is sitting, because the weight-bearing force that caused the collapsed arch is relieved. The arch also returns when she stands on her tip toes (Fig. 4-29B), or with passive extension of the metatarsophalangeal joint of the great toe, the "toe-raise test," because of the windlass effect of the plantar fascia (Fig. 4-29C).The clinician uses these tests to document that this patient has ligamentous laxity with flexible pes planus, a benign condition that usually does not benefit from treatment.

THE ORTHOPAEDIC EXAMINATION FROM 4 TO 10 YEARS OF AGE

A 7-Year-Old Boy Is Referred for Evaluation of Right Groin Pain and a Limp. The family first noted that he was limping on the right side after a soccer game 2 months ago. The limp went away, but 3 days later he complained of right groin pain and they noticed that he was limping again. They went to their pediatrician, who questioned whether he may have pulled a muscle while playing soccer. The pediatrician documented that he was in the 5th percentile for height and the 95th percentile for weight. The pain and limp are worse with activity and relieved by rest. He is otherwise in excellent health.

It is unusual to sustain a groin muscle injury at this age, and symptoms from a groin muscle injury will typically improve in 2 to 3 weeks. If the child was black, the clinician may consider that he may have sickle cell disease with a bone infarct involving the proximal femur. A bone infarct in a patient with sickle cell disease will typically present with the sudden onset of pain in the groin, rather than having pain and limping for 2 months. A child with Legg-Calvé-Perthes disease will often complain of pain in the groin and may have short stature and a delayed bone age. It is important to remember that a child with Legg-Calvé-Perthes disease may

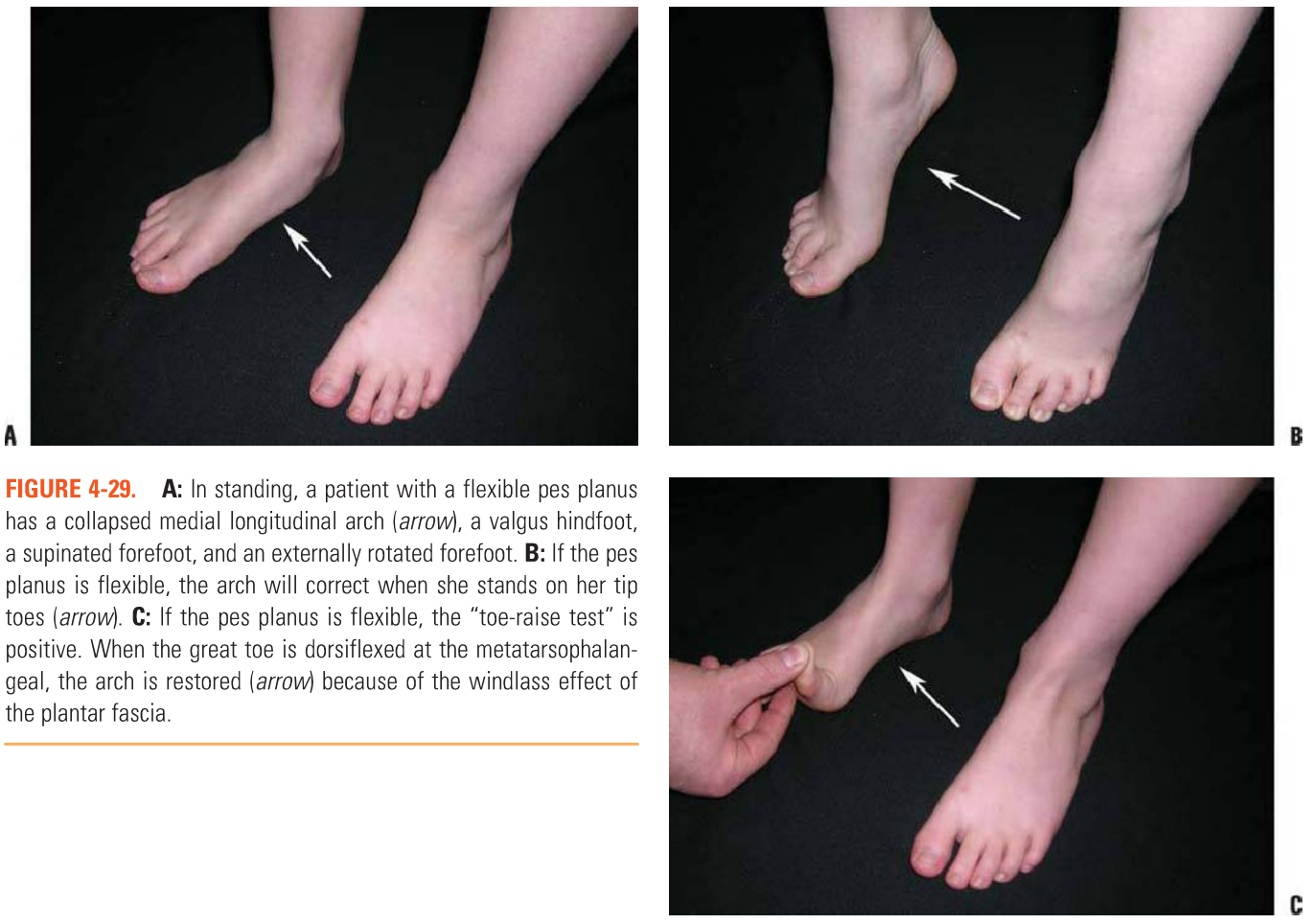

FIGURE 4-29. **A:** In standing, a patient with a flexible pes planus has a collapsed medial longitudinal arch (*arrow*), a valgus hindfoot, a supinated forefoot, and an externally rotated forefoot. **B:** If the pes planus is flexible, the arch will correct when she stands on her tip toes (*arrow*). **C:** If the pes planus is flexible, the "toe-raise test" is positive. When the great toe is dorsiflexed at the metatarsophalangeal, the arch is restored (*arrow*) because of the windlass effect of the plantar fascia.

develop symptoms well after the actual onset of the disease. Children with Legg-Calvé-Perthes disease go through several stages that can be summarized as destructive and reparative phases (19). The majority of symptoms develop early during the destructive phases.

A child with multiple epiphyseal dysplasia may have short stature and may have pain and a limp. Multiple epiphyseal dysplasia is inherited as an autosomal dominant trait, so there may be a family history of the disorder. The insidious onset of pain and a limp may develop in a child with a bone cyst or tumor involving the proximal femur. A child with an osteoid osteoma involving the proximal femur will often complain of night pain that is relieved by aspirin. This boy is 7 years old and osteoid osteomas typically develop in older children.

The physical examination begins by asking the child to walk in the hall. A child with pain and a limp may have an antalgic (painful) limp during gait. This is characterized by a decreased time in the stance phase on the involved side. The clinician also notes swaying or bending of the trunk over the painful hip, to decrease the joint reactive forces. This is termed a Trendelenburg gait pattern and is an important clinical observation, because it leads the clinician to suspect a hip problem. A patient with a Trendelenburg gait pattern will usually have a positive Trendelenburg test (Fig. 4-24). After observing the child's gait pattern, the clinician examines the back and upper and lower extremities, looking for any asymmetry between the symptomatic side and the uninvolved side. A child with Legg-Calvé-Perthes disease and synovitis involving the hip will typically have a loss of internal rotation, abduction, and extension. The loss of internal rotation is usually the most pronounced and is best demonstrated by examining the child in the prone position with the hips in extension (Fig. 4-8).

In the supine position, each hip is flexed to 90 degrees, and gently internally and externally rotated through a range of motion. The clinician notes the amount of internal and external rotation of each hip and feels for any involuntary muscle guarding. Guarding usually indicates that the child has synovitis in the hip with an associated hip joint effusion. In a child with Legg-Calvé-Perthes disease, the finding of persistent synovitis is associated with a guarded prognosis (20). If there is decreased internal rotation without guarding, it may indicate a retroversion deformity of the femoral neck which is often seen in children with developmental coxa vara. This boy likely has Legg-Calvé-Perthes disease, so anteroposterior and frog pelvis radiographs are recommended.

A 6-Year-Old Boy in the Emergency Room Has Severe Pain and Swelling of the Left Elbow After Falling from the Monkey Bars at School. This boy was apparently in satisfactory health until earlier today, when he fell from the monkey bars at school and complained of severe pain in his left elbow. The school nurse called the family, and they picked him up at school and took him immediately to the emergency room. He was evaluated by the emergency room physician who believes that he may have a fracture of the distal left humerus.

In this situation, the boy and his family are anxious about the accident and apprehensive about being in the emergency room. The patient is usually found on a gurney, with the elbow in a temporary splint. The history of present illness is important because the mechanism of injury reflects the magnitude of the injury and the likelihood of an associated neurovascular injury. The child recalls falling about 6 ft landing on his outstretched arms. A fall on an outstretched arm is a mechanism that can cause a distal humerus fracture, an elbow dislocation, a forearm fracture, a distal radius fracture, or a combination of these injuries. The frequency of associated neurovascular injuries correlates with the magnitude of injury. The past history may be helpful to detect an underlying disorder such as osteogenesis imperfecta. If the patient had osteogenesis imperfecta, he may have a pathologic fracture. A pathologic fracture is a fracture through weakened bone. Pathologic fractures typically are minimally displaced with minimal swelling, and it is unusual to have a neurovascular injury in association with a pathologic fracture. Pathologic fractures in children heal normally in most cases.

The child is reassured that his family can stay with him during the physical examination. After a general examination of the spine and lower extremities to evaluate for other injuries, the splint is removed. The uninjured upper extremity is examined first, so the patient is more at ease with the examination. The injured arm is then observed and compared with the uninjured side. Observation demonstrates marked swelling and ecchymosis over the distal humerus and elbow, findings consistent with a supracondylar fracture of the distal humerus. The clinician gently palpates the distal humerus to locate the point of maximum tenderness. The point of maximum tenderness will be on the tension side of the fracture, because there is more soft-tissue injury on the tension side than the compression side.

In a patient with a supracondylar fracture, the immediate concern is whether there are associated neurovascular injuries. Prior to treatment, a complete neurocirculatory examination of the forearms and hands is performed to document pulses, capillary fill, pain, light touch, strength, and range of motion of the fingers. A detailed motor and sensory examination of the median, anterior interosseus, ulnar, and radial nerves is conducted. A supracondylar fracture can interfere with the circulation to the hand by directly injuring the brachial artery, kinking the artery, or by causing too much swelling in the volar compartment of the forearm (21, 22).

A "compartment syndrome" may develop before or after treatment. A compartment syndrome develops when there is too much swelling within a closed space. After a supracondylar fracture, the compartment that most often develops excessive swelling is the volar compartment of the forearm. When the pressure in the compartment surpasses the systolic blood pressure, it will obliterate the radial and ulnar pulses at the wrist. A compartment syndrome may be first detected by noticing that the patient is experiencing pain that seems out of proportion to the physical findings. Another early sign is pain to passive stretching of the ischemic muscles. In a volar compartment

syndrome, the flexor muscles are ischemic, so the patient may complain of pain with passive extension of the fingers. Early detection is crucial because once the pulses are absent, the muscles in the forearm may already be necrotic. When the necrotic muscles develop fibrosis and scarring, a "Volkmann ischemic contracture" develops causing a flexion deformity of the wrist and fingers that can markedly interfere with hand function. If there is any question about a possible compartment syndrome, urgent measuring of compartmental pressures is crucial, and early fasciotomy of the compartments is recommended.

To evaluate the sensory component of a nerve in a 6-year-old boy, it is accurate and painless to test two-point discrimination using a paper clip, comparing the injured side with the uninjured side (Fig. 4-30). The index (median nerve sensory distribution) and little finger (ulnar nerve sensory distribution) are tested; most patients can distinguish between one point and two points if they are separated by more than 2 to 4 mm. The radial nerve is tested checking the sensation in the dorsal web space between the thumb and the index finger (sensory), and by asking the patient to extend his fingers (motor). The median nerve is tested by checking the sensation on the volar aspect of the index finger (sensory), and asking the patient to flex the long and ring fingers (motor). The anterior interosseous nerve has no sensory component, but the motor component can easily be evaluated by having him form a ring between the thumb and index finger. If he is unable to form a ring because of weakness of the flexor pollicis longus and the flexor digitorum profundus of the index finger, it indicates an anterior interosseous nerve palsy (Fig. 4-31). Another way to test the motor function of the anterior interosseous nerve is to hold the index finger in extension at the metacarpophalangeal and proximal interphalangeal joints and ask the patient to flex the tip of the finger (Fig. 4-32). The ulnar nerve is tested by checking the sensation on the volar aspect of the little finger (sensory), and asking the patient to spread his fingers apart (motor). The last muscle innervated by the ulnar nerve is the first dorsal interosseous muscle. This muscle can be tested by placing a finger on the radial side of the distal phalanx and another finger on the muscle belly of the first dorsal interosseous muscle. The patient is asked to push against the finger on the distal phalanx, and the clinician palpates a contracture of the first dorsal interosseous muscle if motor function is intact (Fig. 4-33).

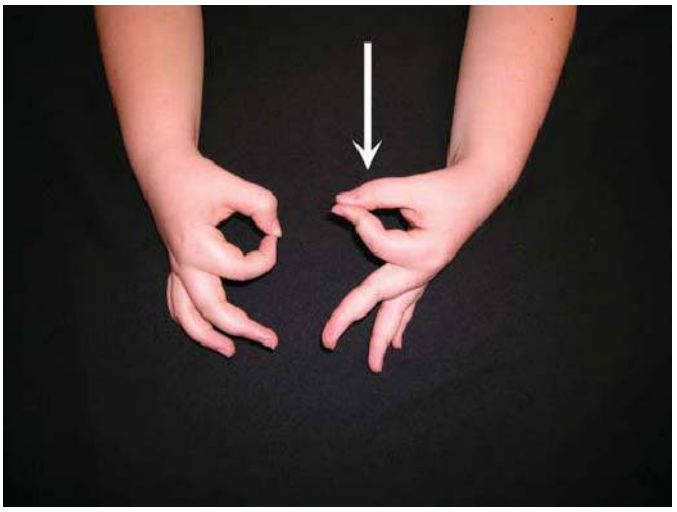

FIGURE 4-31. If the patient is unable to form a ring between the thumb and index finger because of weakness of the flexor pollicis longus and the flexor digitorum profundus of the index finger (*arrow*), it indicates an anterior interosseous nerve palsy.

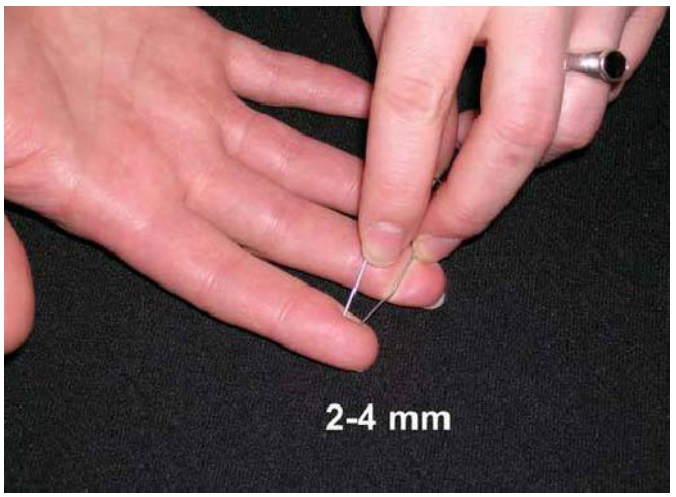

FIGURE 4-30. To evaluate the sensory component of a nerve in a child, it is accurate and painless to test two-point discrimination using a paper clip, comparing the injured side with the uninjured side. Most people have two-point discrimination of 2 to 4 mm in the index (median nerve sensation) and little fingers (ulnar nerve sensation).

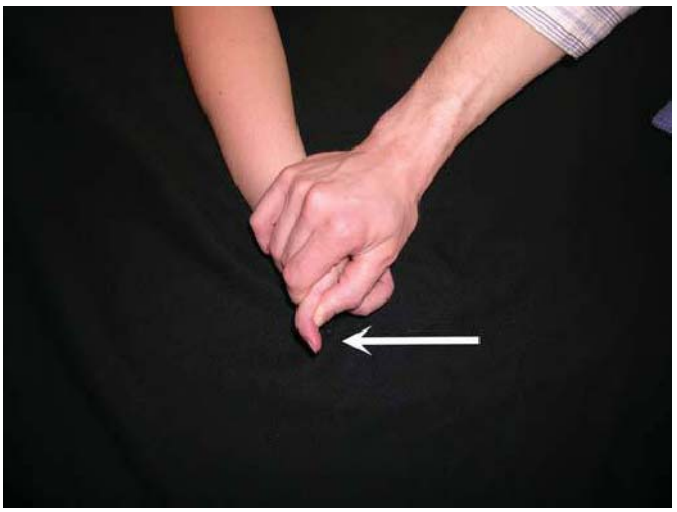

FIGURE 4-32. To test the motor function of the anterior interosseous nerve, the clinician holds the index finger with the metacarpophalangeal and proximal interphalangeal joints in extension, and asks the patient to flex the tip of the finger (*arrow*). Inability to flex the tip of the index finger indicates an anterior interosseous nerve palsy.

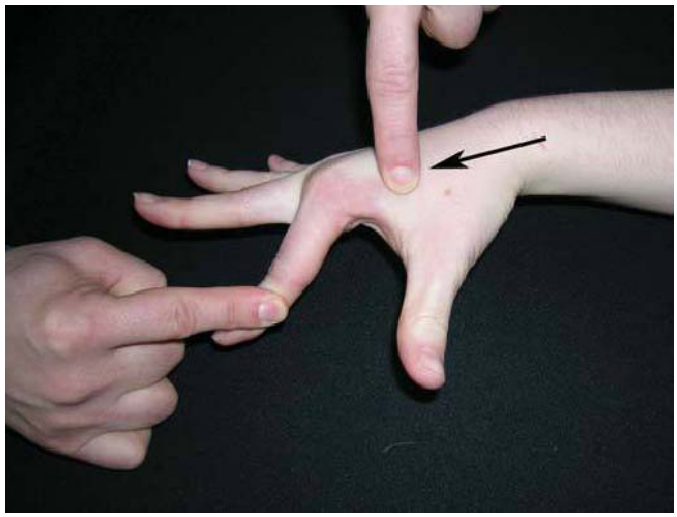

FIGURE 4-33. The first dorsal interosseous muscle is tested by flexing the metacarpophalangeal of the index finger to 60 degrees and placing a finger on the radial side of the distal phalanx and another finger on the muscle belly of the first dorsal interosseous muscle. The patient is asked to push the index finger in a radial direction, and a contraction of the first dorsal interosseous muscle is palpable (*arrow*) if motor function is intact.

If the patient is apprehensive and experiencing severe pain, the physical examination may be compromised. If this occurs, it is important to document the problem in the medical record. In this case, a supracondylar fracture of the distal humerus is suspected, so anteroposterior and lateral radiographs of the elbow are recommended.

A 9-Year-Old Boy Is Referred for Painless Swelling in the Back of His Knees. The patient's grandmother first noticed a swelling in the back of both of her grandson's knees during the summer while playing at the beach. The patient never noticed the masses until they were pointed out to him. He cannot recall any history of trauma to his knees. Since the masses have been pointed out to him, he has noticed that they get bigger and smaller most notably with exercise. He also notes a dull ache in the area behind the knees that is aggravated by increased activity. He denies any weakness, numbness, or loss of function in the low extremities. He has not had any problems with fatigue, weight loss, or fevers and has otherwise been doing well.

The clinician understands that although soft-tissue masses in children are common and almost always benign (23), it is extremely important and sometimes difficult to differentiate between benign and malignant soft-tissue lesions. The most common benign and malignant soft-tissue masses seen in children are listed in Table 4-5. Unlike bone tumors where the physical examination and radiographs are equally important in developing a differential diagnosis, with soft-tissue tumors the differential diagnosis is almost entirely reliant on the history and physical examination.

TABLE 4-5 Common Benign and Malignant Soft-Tissue Masses in Children

Benign	Malignant
Lipoma	Rhabdomyosarcoma
Hemangioma	Synovial sarcoma
Baker cyst	Well-differentiated liposarcoma
Ganglion cyst	Extraskeletal chondrosarcoma
Fibrous tumors	Extraskeletal osteosarcoma
Myositis ossificans	

The majority of soft-tissue sarcomas are painless masses until they become large enough to impinge upon the neurovascular structures. Conversely, many benign pediatric soft-tissue masses present with symptoms. Intramuscular hemangiomas and synovial cysts can present with a waxing and waning dull ache due to changes in blood flow and size during activity and rest. Benign fibrous tumors, such as nodular fasciitis, myositis ossificans, and glomus tumors can be very painful. Some soft-tissue tumors can mimic soft-tissue neoplasms. Epitrochlear lymph nodes secondary to Bartonella hensela (cat scratch disease), foreign-body granuloma, and intramuscular inflammatory reactions to immunizations are well known for generating a confusing clinical and radiologic scenarios. Soft-tissue sarcomas metastasize to the lungs primarily; however, a small subset of sarcomas, specifically rhabdomyosarcoma, alveolar soft parts sarcoma, clear cell sarcoma, epithelial sarcoma, and synovial sarcoma (RACES), will locally metastasize to regional lymph nodes. Therefore, palpation of regional lymph nodes for increases in size is an important part of the physical examination in this patient.

On physical examination, the size, location, consistency, and mobility of the mass or tumor are key parameters to evaluate. Masses that are >5 cm in diameter, firm, fixed, and deep to the fascia should be considered sarcomas until proven otherwise (24). Benign soft-tissue masses are typically soft and mobile. These findings are important because mobility of the tumor reflects the fact the tumor has not invaded the fascia and points to a benign lesion. Benign nerve sheath tumors, such as Schwannomas, arise from the epineurium and will be extensively mobile in a medial to lateral direction, but firmly fixed in a cephalad to caudad direction in line with the nerve. Lipomas and hemangiomas are described as doughy in texture and cysts are easily compressible. Ganglion cysts will occur adjacent to or attached to a joint capsule or tendon sheath. Fluid-filled lesions such as a popliteal cyst (Baker cyst) will transilluminate with a penlight or flashlight. To perform this test on a patient with a Baker cyst, the clinician has the patient lie prone on the exam table in a darkened room and extend the knee while the clinician places a penlight against the skin. If the patient has a Baker cyst, the entire cavity should be illuminated by the penlight. Absence of any dark nonilluminated areas within the lesion helps confirm the diagnosis of a pediatric Baker cyst. If the patient has a hemangioma, the

clinician may occasionally palpate a thrill or audible bruit over the lesion.

Masses that increase in size over time should raise a red flag and warrant consideration for biopsy, whereas masses that have been present for a long time are most likely benign. Two exceptions to this rule include synovial cell and clear cell sarcomas as these malignant tumors are known to frequently grow slowly. Two other exceptions to this rule include nodular fasciitis and desmoid tumors as these benign tumors are rapidly growing and locally invasive.

Large, firm, deep masses should raise a red flag requiring further workup and often warrant a biopsy. Plain radiographs can identify soft-tissue mineralization, but this does not differentiate between benign and malignant lesions. Magnetic resonance imaging with gadolinium contrast is the imaging study of choice for the differential diagnosis and treatment of soft-tissue tumors.

After careful examination of this patient, both tumors are located on the posteromedial aspect of the knees and are best seen with the patient standing and looking at him from behind (Fig. 4-34). They are relatively large, and both tumors are somewhat mobile and transilluminate with a penlight. These finding are consistent with bilateral Baker cysts that originate from the joint capsule of the knee and protrude between the medial head of the gastrocnemius and the semimembranosus tendons. Since Baker cysts have a high probability of spontaneous resolution in children, close observation is recommended. If there is any doubt about the diagnosis or the family has concerns, the diagnosis can be confirmed by ultrasonography.

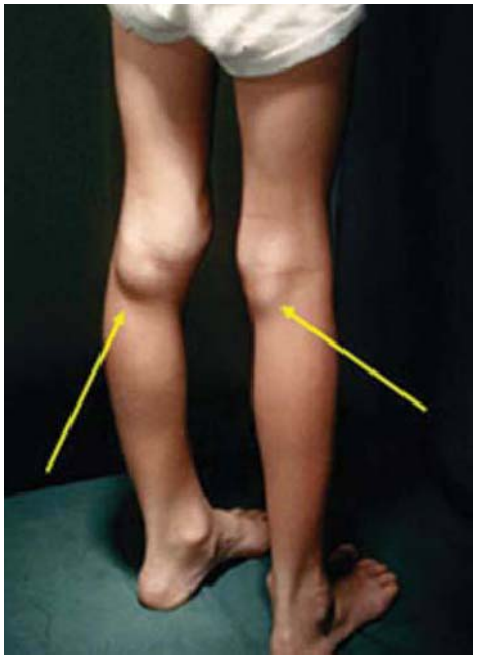

FIGURE 4-34. Bilateral tumors located on the posteromedial aspect of the knees best seen from behind with the patient standing (*arrows*). They are relatively large, somewhat mobile, and transilluminate with a penlight. These findings are consistent with bilateral Baker cysts.

A 10-Year-Old Boy Is Referred for Evaluation of Right Heel Pain That Is Aggravated by Playing Soccer. The family noticed that he began complaining of right heel pain 1 month ago after playing soccer. The pain is worse in the evenings, particularly if he played soccer earlier in the day. He does not have any pain in the left foot or ankle. The pain seems to be aggravated by running and relieved by rest. The family has noted mild swelling over the right heel. He is otherwise in excellent health.

The history is consistent with calcaneal apophysitis, also termed "Sever disease," but the differential diagnosis includes tumor, infection, bone cyst, tarsal coalition, leukemia, Reiter syndrome, and juvenile arthritis. Calcaneal apophysitis is the most common cause of heel pain in the immature athlete and is more common in boys (25). Symptoms develop bilaterally in approximately 60% of cases. In 1912, Sever described the condition as an inflammatory injury to the apophysis associated with muscle strain, but recent investigators attribute the symptoms to overuse and repetitive microtrauma. This patient denies any morning pain or stiffness, as one might see in patients with juvenile arthritis. He denies any pain at night, as might be seen in a patient with a tumor or bone cyst. Heel pain that is persistent may be a sign of childhood leukemia, so it is important to ask about any associated symptoms.

On physical examination, the spine, upper extremities, hips, and knees are within normal limits. The feet appear symmetric with no swelling, erythema, or skin changes. The pain is located right over the calcaneal apophysis and is aggravated by medial and lateral compression of the apophysis; this is termed the "heel-squeeze test" (Fig. 4-35). There is no pain at the insertion of the Achilles tendon, as would be seen in a patient with Achilles tendonitis, and there is no pain at the origin of the plantar fascia, as would be seen in a patient with plantar fasciitis. Achilles tendonitis and plantar fasciitis, although common in adults, are not frequently seen in children. Ankle dorsiflexion is tested with the forefoot fully supinated, locking the subtalar and tarsal joints, to avoid masking an Achilles tendon contracture secondary to hypermobility at the subtalar and tarsal joints. Ankle dorsiflexion on the left is to 30 degrees and on the right is only to 20 degrees. It is common to have associated heel cord tightness in a patient with calcaneal apophysitis. In the standing position, he has mild pes planovalgus and forefoot pronation; conditions also seen in association with calcaneal apophysitis. Calcaneal apophysitis is an overuse syndrome and the symptoms should subside with activity modification. Close follow-up is recommended to document symptom resolution.

A 5-Year-Old Boy Is Referred for Evaluation Because He Is Walking on His Toes. The family first noted that he walked on his toes when he began walking

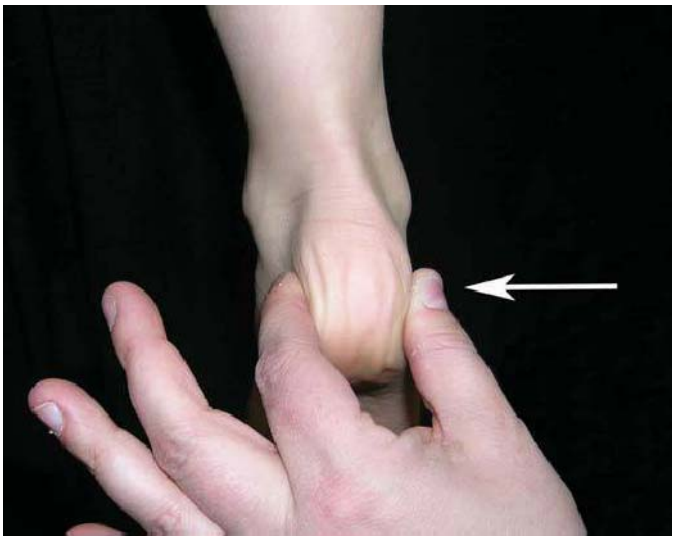

FIGURE 4-35. A patient with calcaneal apophysitis (Sever disease) has pain over the calcaneal apophysis. The pain is reproduced by medial and lateral compression of the apophysis; this is termed the "heel-squeeze test" (*arrow*).

at 2 years of age. Although able to walk with his feet flat on the floor, he walks on his toes 95% of the time. The birth history reveals that he was born after a 28-week gestation, when his mother spontaneously went into labor. The birth was via normal vaginal delivery with a birth weight of 1400 g (3 lb 1 oz). The perinatal course was complicated, and the patient was hospitalized in the NICU for 6 weeks because of respiratory problems. The developmental history reveals that he sat at 11 months and walked at 2 years of age. The family first noted that he was right-handed at 12 months of age when he preferred playing with toys using the right hand. He has been receiving physical, occupational, and speech therapy through an early intervention program.

The boy wore shorts and T-shirt for the office visit so he would not have to change clothes. The exam begins by asking him to walk in the hall with his mother. He walks on his toes, but will occasionally bring the heel to the floor. Sutherland et al. reported that a mature gait pattern is well established at the age of 3 years (26). Normal gait has a heel-toe pattern in stance phase, beginning with heel strike, followed by foot flat, and ending with toe-off. This patient has a toe-toe gait pattern and occasionally has a toe-heel gait pattern. In normal gait during early stance, the foot plantarflexes between heel strike and foot flat. This early ankle plantarflexion is termed the "first rocker." In midstance, there is forward rotation of the leg over the foot, and the ankle dorsiflexes to accommodate this forward motion. This ankle dorsiflexion is termed the "second rocker." In terminal stance, the ankle plantarflexes at push off and this plantarflexion is termed the "third rocker." When this patient ambulates with a toe-toe gait pattern, there is a loss of the first rocker and a decrease of the second and third rockers. When he ambulates with a toe-heel gait pattern, the first rocker is reversed as the ankle dorsiflexes to get to foot flat, and there is a decrease of the second and third rockers.

His gait pattern is not symmetrical, as he spends more time in the stance phase on his right side, compared with the left. This is an important observation, because a patient with muscular dystrophy or idiopathic toe walking will typically have a symmetric gait pattern. In this patient, the knees do not extend completely at the end of the swing phase, and the hips do not extend completely at the end of the stance phase. When walking at a faster pace, he lacks the symmetric fluid reciprocating swinging motion of the upper extremities. Instead, he postures both upper extremities, left more than right, with the elbows in flexion, the forearms in pronation, and the wrists in flexion. This is an important observation, as posturing of the upper extremities during gait is commonly seen in patients with spastic cerebral palsy. During gait, he is noted to have a foot-progression angle of 10 degrees of inward rotation on the left and 5 degrees of inward rotation on the right (Fig. 4-7).

After observing the patient's gait, the physical examination includes the spine, upper, and lower extremities. The spine is examined from the back with the patient standing looking for any asymmetry. The clinician's hands are placed on the patient's iliac crests; the right iliac crest is 5 mm higher than the left, indicating a slight limb-length discrepancy, with the right longer than the left. Patients with cerebral palsy and spastic diplegia will often have some asymmetry, and the lower extremity will often be slightly shorter on the more involved side. The patient is then asked to bend forward at the waist, as if he is touching his toes, and the examiner observes for a rib or lumbar prominence that may be associated with a spinal deformity.

The patient is then asked to sit for the upper extremity examination. He is asked to pick up an object, to determine if there is hand preference, and to see if he can do it with both hands. Grip strength is tested by having the patient squeeze the clinician's index and long fingers of both hands at the same time. Pinch strength is tested by having the patient pick up a pen between the index finger and the thumb. Stereognosis is tested by placing a known object, such as a coin, into the hand, and asking the patient to identify the object without looking at it. The shoulders, elbows, forearms, and wrists are taken through a full range of motion, to determine if there are any contractures. A patient with spastic cerebral palsy may have an adduction contracture of the shoulder, a flexion contracture of the elbow, a pronation contracture of the forearm, a flexion contracture of the wrist, and a thumb-in-palm deformity in the hand.

The patient is placed supine for examination of the lower extremities. The hips are passively taken through a full range of motion. Patients with spastic cerebral palsy will often have flexion and adduction contractures of the hips. The Thomas test or the prone hip extension test (Staheli test) can be used to examine for a hip flexion contracture. The Thomas test

is performed by flexing one hip completely, to flatten the lumbar spine, and observing the amount of residual flexion of the other hip. The residual flexion represents the hip flexion contracture (Fig. 4-36A). The prone hip extension test is performed by placing the patient prone with the lower extremities flexed over the end of the table. This position flattens the lumbar spine leveling the pelvis. One hip remains flexed at 90 degrees; the clinician gradually extends the other hip while palpating the pelvis (27). As soon as pelvic motion is detected, the amount of residual hip flexion represents the flexion contracture (Fig. 4-36B). A flexion contracture in a patient with spastic cerebral palsy is often secondary to an iliopsoas contracture, but may be secondary to a rectus femoris contracture. The Duncan-Ely test, sometimes referred to as the "prone rectus test," is used to test the rectus femoris muscle. Since the rectus femoris muscle spans both the hip and the knee, this test is performed in the prone position. With the hip extended, the knee is flexed quickly while the clinician looks for arise of the buttocks and feels for increased tone in the limb. If the hip spontaneously flexes, causing the buttocks to rise off the table, it indicates a contracture of the rectus femoris muscle. A positive Duncan-Ely test is an accurate predictor for rectus femoris dysfunction during gait (Fig. 4-37) (28).

Internal and external rotation of the hips can be tested in the supine or prone position, but we prefer the prone position (Figs. 4-8 and 4-9). Patients with spastic cerebral palsy often have increased anteversion of the proximal femur, which causes an increase in internal rotation and a decrease in external rotation of the hips. In contrast, patients with developmental coxa vara often have a retroversion deformity proximal femur, which causes an increase in external rotation and a decrease in internal rotation of the hips.

In the supine position with the hips flexed to 90 degrees, the hips should abduct symmetrically to at least 75 degrees. Limited abduction, particularly if associated with flexion contracture, may indicate hip subluxation or dislocation (Fig. 4-5). The Phelps-Baker test is used to determine the hamstring contribution to the hip adduction contracture. This test is performed with the patient in the prone position, and the amount of hip abduction with the knees flexed is compared to that with the knees extended. The amount of decreased abduction with the knees extended represents the contribution of the medial hamstrings to the adduction contracture. The Ober test is used to examine for a hip abduction contracture. The Ober test is performed in the lateral decubitus position, with the lower limb in the knee-chest position. The hip on the upper limb is extended and adducted with the knee extended and with the knee flexed (29). The upper limb should easily adduct to the table, and any loss of adduction represents the hip abduction contracture (Fig. 4-38). The amount of increased abduction with the knee extended compared with the knee flexed represents the contribution of the tensor fascia lata to the abduction contracture. A patient with spastic cerebral palsy will usually develop an adduction contracture of the hip, whereas a patient with poliomyelitis will often develop an abduction contracture.

Knee range of motion is examined with the patient supine on the exam table. The range should be from 0 to 130 degrees.

FIGURE 4-36. **A:** The Thomas test is performed by flexing one hip to the knee-chest position, flattening the lumbar spine and leveling the pelvis, while allowing gravity to extend the hip that is being examined. Any residual flexion represents the hip flexion contracture (60 degrees in this patient). **B:** The prone hip extension test is performed in the prone position with the lower extremities flexed over the end of the table flattening the lumbar spine leveling the pelvis. One hip remains flexed at 90 degrees, while the clinician simultaneously extends the other hip while palpating the pelvis (*arrow*). As soon as pelvic motion is detected, the amount of residual hip flexion represents the flexion contracture.

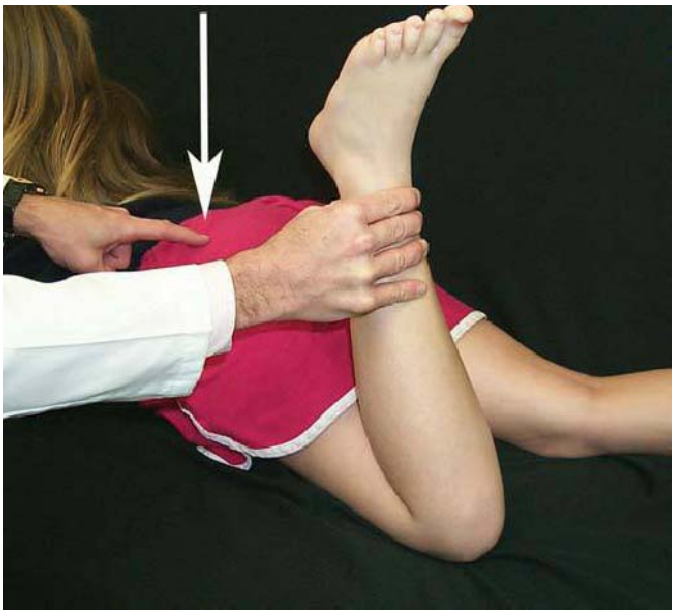

FIGURE 4-37. The Duncan-Ely test is performed in the prone position because the rectus femoris muscle spans both the hip and the knee. With the hip extended, the knee is flexed quickly while the clinician looks for arise of the buttocks (*arrow*) and feels for increased tone in the limb. If the hip spontaneously flexes, causing the buttocks to rise off the table, it indicates a contracture of the rectus femoris muscle.

FIGURE 4-38. The Ober test is performed in the lateral decubitus position with the lower limb in the knee-chest position. The hip on the upper limb is extended and adducted with the knee extended and with the knee flexed (*arrow*). The upper limb should easily adduct to the table, and any loss of adduction represents the hip abduction contracture.

A flexion contracture may be caused by a hamstring contracture. A hamstring contracture is detected by performing a straight-leg-raising test (Fig. 4-39A). Straight-leg raising should range from 60 to 90 degrees. Limited straight-leg raising often indicates a contracture of the hamstring muscles, but it may be associated with a neurologic problem such as a tethered spinal cord. A hamstring contracture can also be detected by measuring the popliteal angle. To measure the popliteal angle, the hip is flexed to 90 degrees and the knee is gradually extended to the first sign of resistance. The angle between the thigh and the calf is the popliteal angle (Fig. 4-39B). This popliteal angle

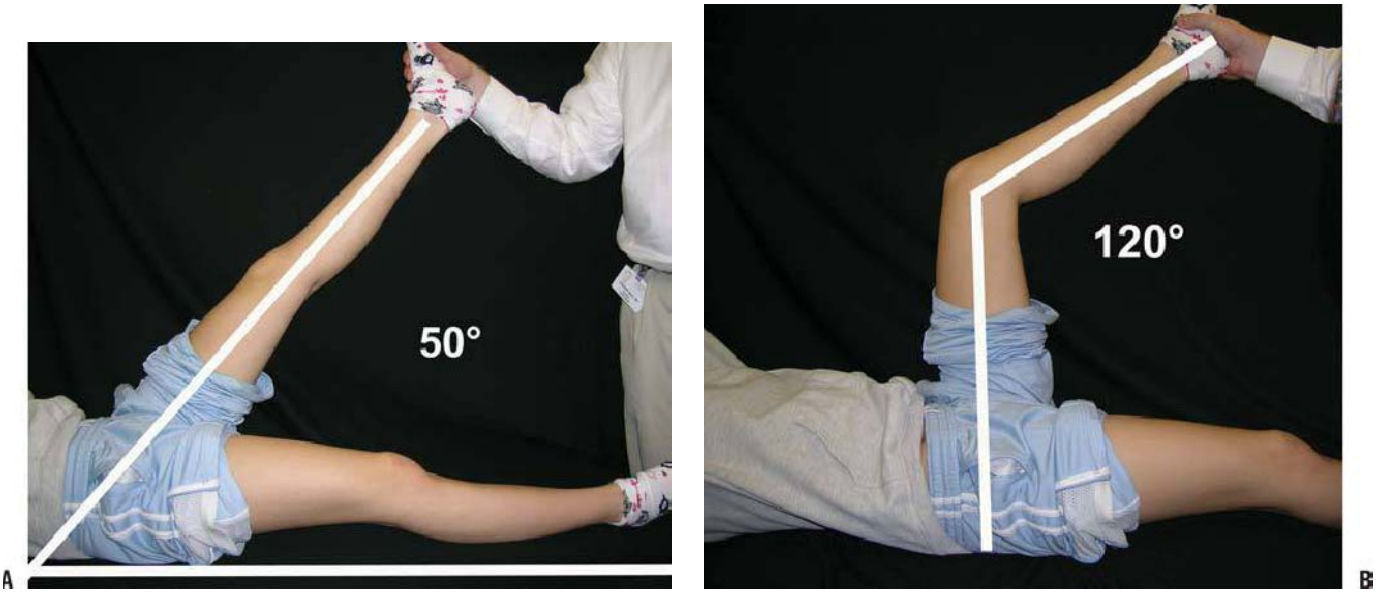

FIGURE 4-39. **A:** With the patient supine, the clinician gradually raises one lower extremity by flexing the hip with the knee in extension. The straight-leg-raising test measures the angle between the lower limb and the tabletop (50 degrees in this patient). **B:** With the patient supine, the clinician gradually flexes the hip and knee to 90 degrees. The knee is gradually extended to the first sign of resistance. The angle between the thigh and the calf is the popliteal angle (120 degrees in this patient). This popliteal angle should be distinguished from its complement, which is also called the popliteal angle by some investigators.

should be distinguished from its complement, which is also called the popliteal angle by some investigators (12). Elmer et al. (30) chose to call the angle between the calf and the thigh the popliteal angle, as originally described by Amiel-Tison, because they believed it was a more appropriate description of the angle subtended by the popliteal fossa.

The feet are examined to determine if there is an equinus or equinovarus contracture. The ankles should easily dorsiflex to 30 degrees, plantarflex to 40 degrees, and the hindfoot should be supple. When testing dorsiflexion of the ankle, it is important to supinate the hindfoot, locking the subtalar joint, because hypermobility in the subtalar and tarsal joints can mask an equinus contracture. The decrease in the amount of ankle dorsiflexion with the knee extended, compared to that with the knee flexed, represents the contribution of the gastrocnemius muscles to the equinus contracture; this is termed the Silverskiold test (31). This patient has cerebral palsy with asymmetric spastic diplegia and may have a neuromuscular hip subluxation or dislocation, so an anteroposterior pelvis radiograph is recommended.

A 9-Year-Old Boy with Cerebral Palsy and Spastic Diplegia Is Referred Because His Feet Turn Out and He Fatigues Easily. His mother first noticed that his feet turned out shortly after he began walking at 3 years of age. According to his mother, his feet have gradually deteriorated over the last 4 years to the point where he now "walks like a duck." She has also noticed that over the last 2 years his endurance has decreased to the point where he actually needs to rest several times when she takes him shopping. She states that 2 years ago he walked upright, but now he walks bent over at the knees. His birth history reveals that he was born after a 26-week gestation with a birth weight of 1300 g (2 lb 14 oz). Immediately after birth, he had difficulty breathing. He was intubated and transferred to the NICU for care. He remained in the NICU for 3 months prior to going home. His subsequent development was delayed as he first sat at 14 months and did not walk independently until he was 3 years old. He has been receiving physical therapy services and his therapist has noted tight hamstrings and questions whether the hamstring spasticity may be contributing to his crouch gait pattern.

On physical examination, he ambulates with a crouched gait pattern with pes planus and a foot-progression angle of 45-degree external rotation on the right and 50-degree external rotation on the left (Fig. 4-7). Stance phase is longer on the right compared with the left, and he seems more stable when he stands on the right lower extremity. During gait, he crouches with bilateral hip flexion of 30 degrees and bilateral knee flexion of 40 degrees in midstance. He swings his arms during gait to control his balance during single-limb stance. There is an absent first rocker with his flat-foot gait pattern, an excessive second rocker as the tibia rolls freely over the foot with minimal resistance from the soleus, and a markedly weakened third rocker or lack of push off secondary to weak ankle plantarflexors.

The lack of push off is an important clinical finding as the ankle plantarflexors play a key role in preventing a crouch gait pattern by a mechanism termed the "plantar flexion knee extension couple." In normal gait, during midstance as the tibia rolls freely over the foot, it creates a large external dorsiflexion moment at the ankle that is balanced by an internal ankle plantarflexion moment created primarily by the soleus. This ankle plantarflexion moment drives the tibia and knee posteriorly in the sagittal plane keeping the ground reaction force anterior to the knee creating an extension moment. The resulting plantar flexion knee extension couple generated by the soleus muscle results in an efficient gait pattern with the knee flexed no more than 15 degrees in midstance (32). In this patient, the soleus muscle is not generating enough power to balance the dorsiflexion moment at the ankle. The resulting weakened plantar flexion knee extension couple causes the ground reaction force to fall anterior to the knee causing the crouch gait pattern. To compensate for the decreased plantar flexion knee extension couple, the quadriceps is activated during midstance resulting in increased patellofemoral pressure and considerable energy consumption.

In the supine position, the Thomas test reveals bilateral hip flexion contractures of 25 degrees (Fig. 4-36A). The straight-leg-raising test only reaches 50 degrees bilaterally indicating hamstring contractures (Fig. 4-39A). The hamstring contractures are further evaluated by measuring the popliteal angles, which reveals a popliteal angle of 130 degrees on the right and 120 degrees on the left (Fig. 4-39B). The foot examination reveals dorsiflexion to 35 degrees and plantarflexion to 40 degrees bilaterally.

In the prone position, maximum internal rotation of the hips is 60 degrees bilaterally (Fig. 4-8), and external rotation is 50 degrees bilaterally (Fig. 4-9). The thigh-foot angles (Fig. 4-10) reveal 50 degrees external rotation on the right and 55 degrees on the left (Fig. 4-40). The marked external tibial torsion in this patient decreases the power of the plantarflexor muscles by shortening their joint moments. Although the plantarflexors may be strong, their decreased joint moments result in decreased function, and this loss of function is termed "lever arm dysfunction." Schwartz and Lakin (32) used an induced acceleration analysis model to analyze the vertical support function of the soleus muscle and reported that external tibial torsion of 50 degrees caused a 40% loss of support.

This patient's external tibial torsion is causing considerable lever arm dysfunction of the ankle plantarflexors causing him to crouch and use the quadriceps muscles to compensate for the loss of support. This gait pattern is very inefficient, causing a loss of endurance and early fatigue. He may benefit from bilateral distal tibial osteotomies to correct the external tibial torsion to restore plantarflexion power and improve the function of the plantar flexion knee extension couple.

A 5-Year-Old Boy Is Referred Because He Has Been Limping. The mother first noticed that he seemed to walk funny last year, but he definitely began limping on the

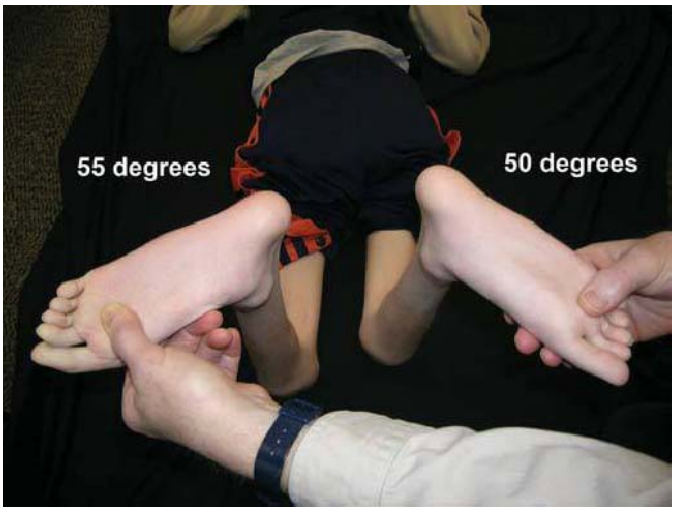

FIGURE 4-40. The thigh-foot angles in this patient are 55 degrees on the left and 50 degrees on the right. This amount of external tibial torsion decreases the power of the plantarflexor muscles by shortening their joint moments. Although the plantarflexors may be strong, their decreased joint moments results in decreased function termed "lever arm dysfunction."

right side shortly after his fifth birthday. He has been limping for 3 months, and the limp is worse at the end of the day when he is tired. He never complains of pain and she has not previously noticed any swelling.

The physical examination begins by observing his gait pattern in the hall. He walks with an obvious limp on the right, but he spends an equal amount of time in stance phase on both limbs, indicating a painless limp. The differential diagnosis of a painless limp is different than that of a painful (antalgic) limp. A painless limp could be caused by DDH or a limb-length discrepancy, whereas a painful limp could be caused by Legg-Calvé-Perthes disease or transient synovitis. If the patient had bilateral DDH, the limp may be subtle with a waddling gait pattern associated with increased lumbar lordosis.

With the boy standing, the clinician places both hands on the iliac crests and notes that the left iliac crest is 2 cm higher than the right, indicating a limb-length discrepancy with the left lower extremity longer than the right. When he is asked to stand on the left leg, the right iliac crest elevates 5 mm. When he is asked to stand on the right leg, the left iliac crest drops 15 mm. The inability of the hip abductor muscles to hold the pelvis is single-limb support is termed a positive Trendelenburg test (Fig. 4-24). Since the patient has no pain, the positive Trendelenburg test indicates weakness of the hip abductor muscles. In a patient with developmental coxa vara, the decrease in the neck-shaft angle decreases the articulotrochanteric distance between the femoral head and the greater trochanter. This disrupts the normal length–tension relationship of the abductor muscles causing weakness.

The hip exam reveals flexion to 130 degrees on the left and 120 degrees on the right. The Thomas test (Fig. 4-36A) reveals extension to 0 degrees on the left and a flexion contracture of 25 degrees on the right. Abduction is to 80 degrees on the left and 50 degrees on the right, and adduction is to 30 degrees bilaterally. Internal rotation is to 60 degrees on the left and only 0 degrees on the right, and external rotation is to 60 degrees on the left and to 70 degrees on the right (Figs. 4-8 and 4-9). These changes in range of motion may be secondary to a retroversion deformity of the proximal femur, often seen in a patient with developmental coxa vara or SCFE. Since SCFE typically occurs during puberty, it would be unlikely in a 5-year-old boy unless he had an underlying endocrine disorder.

A simple method to assess femoral and tibial lengths and foot heights in a patient with a limb-length discrepancy is to first place him in the supine position with the hips flexed to 90 degrees to measure the femoral lengths. The Galeazzi sign (Fig. 4-6) reveals the difference in height of the knees, indicating the difference in the femoral lengths. To measure tibial lengths, including the heights of the feet, he is placed in the prone position with the hips extended and the knees flexed to 90 degrees. The difference in the heights of the heels represents the discrepancy in the length of the tibias plus the heights of the feet (Fig. 4-41). This method, although an estimate of the total limb-length discrepancy, may be more accurate than a CT scan because, unlike the CT scan, it takes into account the heights of the feet.

This patient has a limb-length discrepancy with abductor weakness and a loss of internal rotation of the right hip. These findings are consistent with the diagnosis of developmental coxa vara so an anteroposterior pelvis radiograph is recommended.

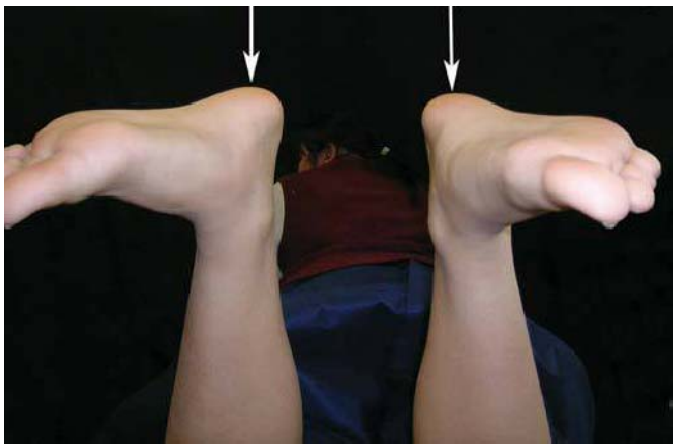

FIGURE 4-41. To measure tibial lengths and foot heights, the patient is placed in the prone position with the hips extended and the knees are flexed to 90 degrees. The difference in the heights of the heels (*arrows*) represents the discrepancy in the length of the tibias plus the heights of the feet.

THE ORTHOPAEDIC EXAMINATION FROM 10 TO 18 YEARS OF AGE

A 13-Year-Old Girl Is Referred for Evaluation of Scoliosis. After a scoliosis screening examination at school, the patient was given a note from the nurse recommending an evaluation for possible scoliosis. The girl's pediatrician detected shoulder asymmetry and a rib prominence and referred her for evaluation. The patient has never noticed any spinal deformity and is active in sports. She occasionally gets pain in the lower back, but this does not interfere with her activities. She denies any problems with bowel or bladder function, and she first began menses 1 month ago, indicating that she is now past her peak growth velocity. The family history reveals that she has two maternal cousins with scoliosis, and one of them required surgery for the spinal deformity. The mother states that she has grown 5 cm (2 in.) in the last 6 months. She is 178 cm (5 ft 10 in.) tall, and her mother is 175 cm (5 ft 9 in.) and her father is 188 cm (6 ft 2 in.) tall.

A history of mild back pain that does not interfere with activities is common in patients with scoliosis. Ramirez et al. (33) evaluated 2442 patients with idiopathic scoliosis and reported that 560 (23%) had back pain at the time of presentation, and an additional 210 (9%) had back pain during the period of observation. In contrast, a history of severe back pain associated with rapid progression of the scoliosis, weakness or sensory changes, bowel or bladder complaints, or balance problems is not typical in a patient with idiopathic scoliosis and suggests a possible intraspinal problem.

The physical examination begins with the patient standing. The trunk shape and balance are observed from the back. The clinician looks for any asymmetry in the neck, level of the shoulders, level of the scapular spines, prominence of the scapulae, surface shape of the rib cage, or the contour of the waist. A patient with lumbar scoliosis convex to the left will have asymmetry of the waist, with the left side being straight and the right side contouring inward, giving the appearance of a limb-length discrepancy. The iliac crest is more accentuated on the concave side, and the patient often interprets this as the right hip sticking out. The skin is observed for any café-au-lait marks or freckling in the axilla that may indicate neurofibromatosis. If the patient is tall and has long prominent fingers (arachnodactyly), it may indicate Marfan syndrome.

If the patient is standing erect and the spine is compensated, the head should be centered directly over the pelvis and a plumb bob suspended from the spinous process of the seventh cervical vertebra should fall directly over the gluteal cleft (Fig. 4-42). If the spine is decompensated to either side, the distance from the plumb bob to the gluteal cleft is recorded in centimeters. The posterior iliac dimples in stance are observed to determine if they are symmetric and level, indicating equal limb lengths. The clinician's hands are placed on the iliac crests to determine if the pelvis is level, or if there is a limb-length discrepancy (Fig. 4-43). If there is a limb-length discrepancy, the difference in the level of the iliac

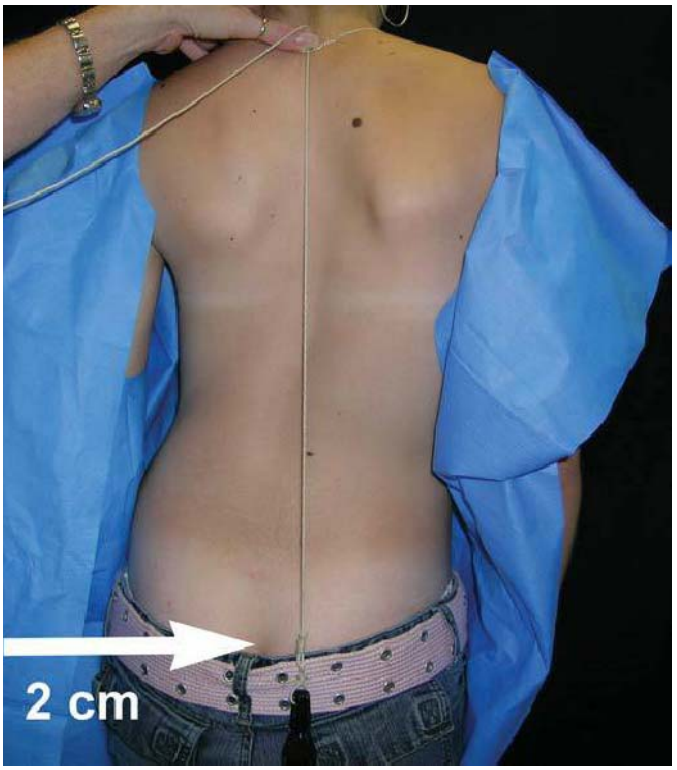

FIGURE 4-42. If the spine is compensated, the head should be centered over the pelvis, and a plumb bob suspended from the spinous process of the seventh cervical vertebra should fall directly over the gluteal cleft. If the spine is decompensated, the distance from the plumb bob to the gluteal cleft is recorded in centimeters (2 cm to the right in this patient).

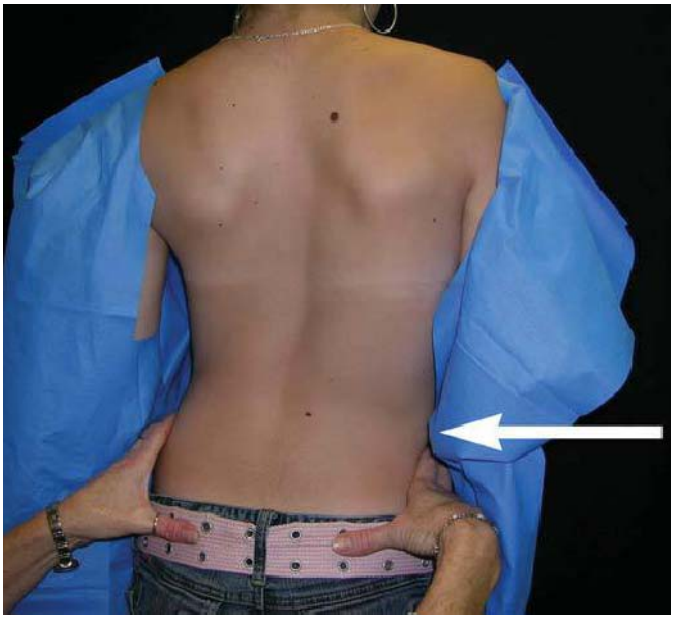

FIGURE 4-43. The patient is observed from the back looking for any asymmetry in the neck, level of the shoulders, level of the scapular spines, prominence of the scapulae, surface shape of the rib cage, contour of the waist, and the level of the iliac crests (*arrow*).

crests is recorded in centimeters. A limb-length discrepancy causes a compensatory postural scoliosis deformity, convex toward the shorter limb, to balance the head over the pelvis. This postural scoliosis will correct when the limb-length discrepancy is corrected by placing an appropriate sized wooden block under the foot of the short leg to equalize the limb lengths. The spinous processes are palpated to determine if there is any focal tenderness, and the patient is asked to arch her back, to see if it causes discomfort (Fig. 4-44). Patients who have a spondylolysis will often have discomfort when the spinous process of the involved vertebra is palpated, or when they attempt to extend the spine.

The patient places the hands together in front of her and bends forward as if she were touching her toes. This is the "Adams forward-bending test" and is one of the most sensitive clinical tests to detect scoliosis (Fig. 4-45). As the patient bends forward, the clinician observes the spine to determine if it is supple and flexes symmetrically. If the patient bends to one side instead of straight ahead, it may indicate a hamstring contracture associated with a spondylolisthesis, disk herniation, or neoplasm. As the patient bends forward, if the spine flexes excessively in the thoracic area, it may indicate Scheuermann disease or kyphosis (Fig. 4.46). When the patient is in the forward-bending position, the clinician looks for any asymmetry of the trunk and measures the angle of trunk rotation, or rib prominence, using a scoliometer (Fig. 4-45) (34). In this patient, the angle of trunk rotation measures 21 degrees at T8 with the right side higher than the left. The angle of trunk rotation or rib prominence reflects the rotational component of the scoliosis deformity that occurs in the axial plane. The most common type of scoliosis is a convex right thoracic curve, in which the vertebrae rotate into the convexity of the curve, causing the ribs to be more prominent posteriorly on

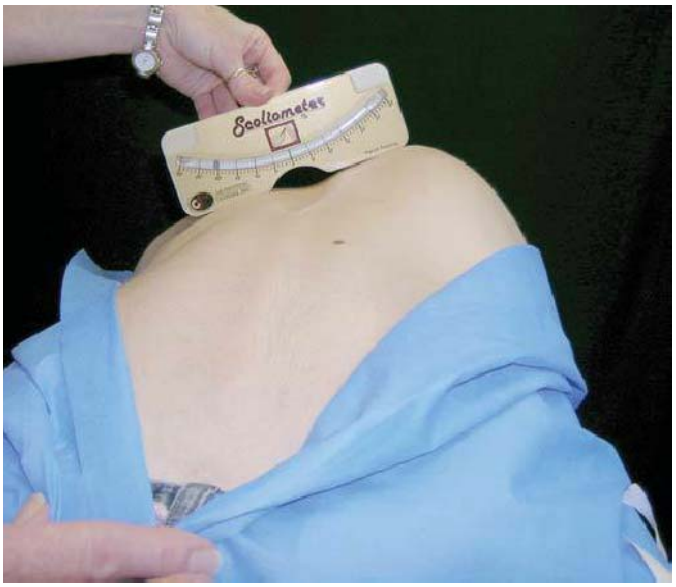

FIGURE 4-45. The Adams forward-bending test is performed by asking the patient to place the hands together in front of her and bend forward at the waist, as if she were touching her toes. As the patient bends forward, the clinician observes the spine to determine if it is supple and flexes symmetrically. Once the patient has bent forward so that the spine is parallel to the floor, the clinician looks for asymmetry of the trunk and measures the angle of trunk rotation using a scoliometer. In this patient, the angle of trunk rotation is 21 degrees at T8.

FIGURE 4-44. The patient is asked to arch her back, to determine if it causes discomfort. Pain or discomfort to palpation in to lower back (*arrow*) or pain that is aggravated by arching the back are important findings often seen in patients with a spondylolysis.

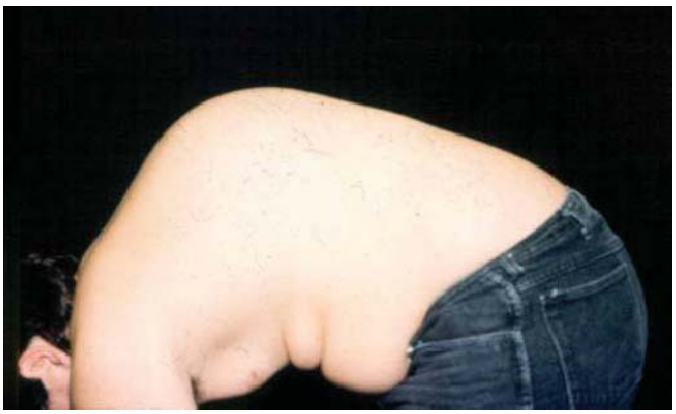

FIGURE 4-46. As the patient bends forward during the Adams forward-bending test, the clinician observes closely to determine if the spine flexes symmetrically. Any excessive flexion in the thoracic area, as seen in this patient, may indicate Scheuermann disease.

the patient's right side. The ribs are also more prominent anteriorly on the patient's left side, which may cause breast asymmetry. While the patient is in the forward-bending position, she is asked to bend to the right and left to assess the flexibility of the scoliosis.

Scoliosis is seen in association with neuromuscular disorders, such as muscular dystrophy, and is also seen in association with spinal cord anomalies, such as a tethered spinal cord. A thorough neurologic examination is essential to rule out a neuromuscular disorder. In standing, the Romberg sign is elicited by asking the patient to place the feet closely together. She then closes her eyes and the clinician looks for any sway or instability. A patient with cerebellar ataxia will sway or move her feet to maintain balance. This test may be helpful because scoliosis is frequently seen in patients with Friedreich ataxia. An evaluation of the upper and lower extremity strength, sensation, and reflexes is essential to rule out an occult neuromuscular disorder. A straight-leg-raising test is performed to look for hamstring tightness or a radiculopathy (Fig. 4-39A). Straight-leg raising to <40 degrees may indicate tight hamstrings associated with a spondylolisthesis, disc herniation, or neoplasm. The abdominal reflexes are tested by gently stroking the side of the abdomen, and the umbilicus should deviate toward the stimulus. Any asymmetry of the abdominal reflexes is important because it may indicate an intraspinal problem.

In a patient with adolescent idiopathic scoliosis, it is important to assess their maturity, because the risk of curve progression is higher in young patients and in patients with larger curves (35). The risk of progression is highest when the patient is at their peak growth velocity. The peak growth velocity typically occurs about 12 months before the onset of menses and 12 months after closure of the triradiate cartilage. Most investigators recommend radiographs if the angle of trunk rotation is >7 degrees, so scoliosis posteroanterior and lateral radiographs are recommended, to be taken with a tube-to-film distance of 183 cm (72 in.) on a 91 cm (36 in.) cassette.

A 14-Year-Old Girl Is Referred for Evaluation of Low Back Pain Aggravated by Playing Soccer. The patient was apparently in satisfactory health until 4 months ago when she developed low back pain after a soccer game. Over the last 3 months, the pain has increased to the point that she is unable to play for more than 5 minutes without resting. She describes the pain as being in the lower back in the L5–S1 area and it is worse on the right side. The pain does not radiate into the buttocks or lower extremities, and it is aggravated by exercise and relieved by rest. Her past medical history reveals no major illnesses or prior hospitalizations.

The physical examination begins by observing her gait and she has a normal heel-toe gait pattern. A patient with low back pain may have subtle changes in gait that can be detected by an astute observer. A patient with spondylolisthesis may have a hamstring contracture that prevents full extension of the knee in terminal swing, causing a decrease in step length and stride length. Step length is the distance from the foot strike of one foot to the foot strike of the other foot. Stride length is the distance from one foot strike to the next foot strike by the same foot. Thus, each stride length includes one right and one left step length (36). In a patient with a severe spondylolisthesis, the hamstring contractures may be so severe that the patient actually walks on their toes with a toe-toe gait pattern.

In standing, the trunk shape and balance are observed from the back. The clinician looks for any asymmetry in the neck, scapulae, shoulders, rib cage, waist, or hips (Fig. 4-43). Low back pain can cause muscle spasms on the side with the pain, causing a scoliosis convex to the opposite side. The paraspinal muscles are palpated to determine if they are in spasm. An osteoid osteoma involving the posterior elements of the spine may be associated with a painful scoliosis. This patient describes increased pain when she attempts to arch her back (Fig. 4-44). Hyperextension of the lumbar spine increases the pressure on the posterior elements, causing a patient with spondylolysis to experience increased pain with this maneuver. This test is important because most patients with back pain will not have increased in pain with this maneuver. The spinous processes of the lumbar vertebrae are palpated to determine if palpation causes discomfort. A patient with a spondylolysis at L5 will often experience pain with palpation of the L5 spinous process because the palpation increases the pressure on the pars interarticularis (Fig. 4-44).

With the patient seated, a motor, sensory, and reflex examination of the upper and lower extremities is performed. A disc protrusion affecting the L5 nerve root may compromise function of the extensor hallucis longus and posterior tibial muscles and is detected by weakness in dorsiflexion of the great toe, weakness in inversion, and a decreased posterior tibial tendon reflex. A L5 disc protrusion may also cause sensory changes over the dorsal and medial aspect of the foot, particularly in the web space between the first and second toes. A disc protrusion affecting the S1 nerve root could compromise function of the gastrocsoleus muscle and is detected by weakness in the gastrocsoleus muscle and a decreased Achilles tendon reflex. Occasionally it is difficult to elicit the Achilles tendon reflex. This problem can be resolved by having the patient kneel on a chair with the feet dangling over the edge. In this position, the reflex hammer typically elicits a good ankle jerk. A patient with an S1 disc protrusion may have sensory changes over the plantar and lateral aspect of the foot.

The patient is placed supine, and a straight-leg-raising test is performed (Fig. 4-39A). Limited straight-leg raising may indicate hamstring tightness associated with spondylolisthesis or nerve root irritation from disc herniation or neoplasm. Young athletes with spondylolysis will often experience increased pain while playing soccer. Debnath et al. (37) evaluated 22 young athletes who had surgery for low back pain associated with a spondylolysis and 13 (59%) were soccer players. This patient's pain may be secondary to a spondylolysis, so radiographs of the lumbar spine are recommended.

A 14-Year-Old Boy Is Referred for Evaluation of Left Knee Pain and Limping. The patient was in satisfactory health until 4 months ago when he developed pain in his left knee. Several weeks later, his mother noticed he was limping on his left leg. The pain and limping has increased and are aggravated by activities. There is no history of injury, and he has not had any swelling in the knee. The past medical history and family history are unremarkable. The personal and social history reveals that he has always been overweight.

A 14-year-old boy who is obese and complaining of left knee pain and a limp should cause the clinician to immediately consider the diagnosis of SCFE. The majority of children with SCFE are obese. Obesity is also associated with femoral retroversion, with anteversion averaging 10.6 degrees in adolescents of average weight, but only 0.4 degrees in obese adolescents (38). Obesity and femoral retroversion increase the mechanical shear stresses across the physis, increasing the risk of slip progression in a patient with SCFE.

On physical examination, he weighs 95 kg (208 lb) (greater than the 95th percentile for weight). In observing his gait pattern, he ambulates with an antalgic (painful) limp on the left lower extremity. He leans his head and trunk to his left during the stance phase. The shifting of weight over the left lower extremity in stance phase decreases the joint reactive forces in the hip and is termed a Trendelenburg gait pattern. A patient with a Trendelenburg gait will usually have a positive Trendelenburg test (Fig. 4-24). He has a shortened stance phase on the left, and his foot-progression angle is 10 degrees of external rotation on the right and 35 degrees of external rotation on the left (Fig. 4-7). In standing, the shoulders, scapular spines, and spine are observed from the back, and no asymmetry is noted. The clinician's hands are placed on the iliac crests, and the left iliac crest is noted to be 1 cm lower than the right, indicating a limb-length discrepancy (Fig. 4-43). In single-limb stance, he is noted to have a negative Trendelenburg test when he stands on his right lower extremity and a positive Trendelenburg test when he stands on his left lower extremity (Fig. 4-24).

In describing his pain, he points to the anterior aspect of the left knee. A patient with SCFE may complain of knee pain, rather than hip, thigh, or groin pain. This phenomenon occurs because the obturator and femoral nerves that supply the hip also supply the knee. A patient with hip pathology complaining of knee pain is a classic example of referred pain. The range of motion of his hips reveals flexion to 130 degrees on the right and 120 degrees on the left. When the right hip is flexed to the knee-chest position, it remains in neutral rotation, but when the left hip is flexed it spontaneously goes into abduction and external rotation. This abduction and external rotation occurs because a patient with SCFE has a retroversion deformity of the proximal femur. The femoral neck displaces anteriorly, through the physis, creating apex-anterior angulation of the proximal femur (39). Abduction is to 70 degrees on the right and 50 degrees on the left. Internal rotation is to 20 degrees on the right and minus 20 degrees on the left (Fig. 4-8). External rotation is to 70 degrees on the right and 85 degrees on the left (Fig. 4-9). These physical findings indicate a retroversion deformity of the left femoral neck, with an increase in external and a decrease in internal rotation of the left hip. An obese adolescent boy with these physical findings has a high probability of having SCFE, so anteroposterior and frog-lateral pelvis radiographs are recommended.

A 14-Year-Old Girl Is Referred for Evaluation of Left Knee Pain and giving Way. The patient states that she was fine until 6 months ago, when she collided with another player in a soccer game and landed directly on her left knee. She had moderate swelling that resolved in 7 days and she gradually resumed playing soccer. The knee felt better after the soccer season, but recurred when she began playing basketball. She describes the pain as being located circumferentially around the kneecap. The pain is aggravated by sitting in the back seat of the car with the knee flexed. The pain is also worse going up and down the stairs.

A patient with anterior knee pain or patellofemoral pain syndrome will often experience pain when sitting with the knee flexed for a prolonged period of time. This finding has been termed a positive "movie sign" from sitting for several hours in the movie theater. In a similar fashion, the pain occurs after sitting in the back seat of a car for several hours. Patients with anterior knee pain will often have increased pain going upstairs and downstairs. The patient may note catching, subpatellar crepitus, and giving way, but true locking is unusual.

On physical examination, the clinician compares the injured knee with the uninjured knee looking for loss of the "dimples" on either side of the patella, indicating an effusion (Fig. 4-47). If the patient does not have an observable effusion, the suprapatellar pouch is milked from medial to lateral moving any fluid into the lateral compartment of the knee. The lateral side is then milked while observing for a fluid wave on the medial side (Fig. 4-48). Visualizing the fluid wave is

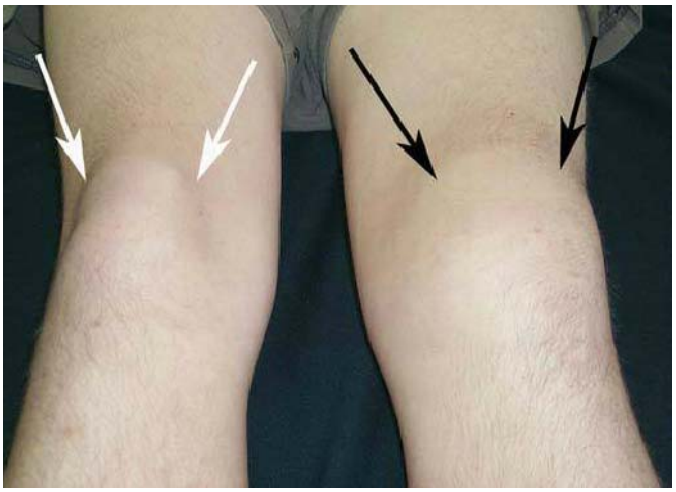

FIGURE 4-47. In this patient, the uninjured right knee has "dimples" (*white arrows*) on either side of the patella. The injured left knee has a large effusion that stretches out the dimples (*black arrows*).

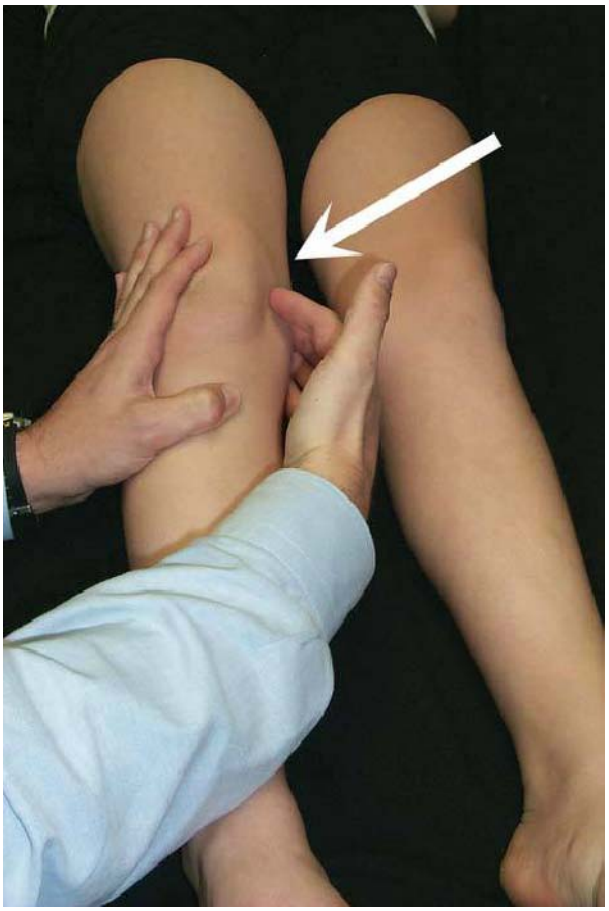

FIGURE 4-48. If a mild knee effusion is suspected, the suprapatellar pouch is milked from lateral to medial moving any fluid into the medial compartment of the knee. As the lateral side is milked, the clinician observes for a fluid wave on the medial side (*arrow*).

the most sensitive test to detect a trace effusion. In describing the pain, she points to the medial and lateral sides of the patella. She has tenderness on the undersurface of the medial and lateral facets of the patella, which is elicited by gently palpating the facets while pushing the patella laterally and medially with the knee in extension. A patient with anterior knee pain may have a contracture of the lateral retinaculum. This is detected by the inability to elevate the lateral margin of the patella when tilting the patella medially and laterally during the tilt test. If the pain is caused by patellofemoral joint reaction forces, it can be reproduced by the "patellar inhibition test." This test is performed in the supine position with the knee in extension. The patient is asked to do a straight-leg raise while the clinician holds the patella distally, preventing it from ascending along the anterior femur (Fig. 4-49). This maneuver increases the pressure between the patella and femur, reproducing the pain in a patient with patellofemoral pain syndrome. If the pain is caused by patellofemoral instability, it can be reproduced by the "patellar apprehension test." This test is performed with the knee flexed to 30 degrees, and the clinician gently pushes the patella laterally (Fig. 4-50).

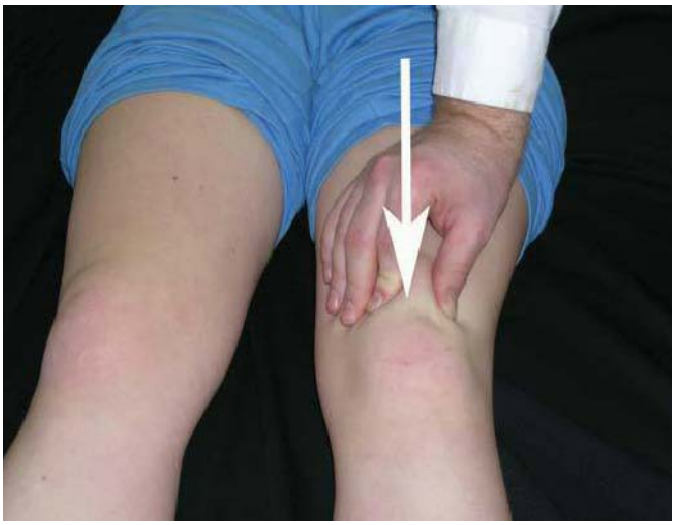

FIGURE 4-49. The patellar inhibition test is performed with the patient supine and the knee in extension. The clinician holds the patella (*arrow*), inhibiting it from ascending along the femur, while the patient performs a straight-leg raise. This maneuver increases the forces in the patellofemoral joint causing discomfort in a patient with patellofemoral pain.

If the patient immediately contracts her quadriceps to prevent the patella from subluxating, the test is positive and often occurs in patients who have previously had a subluxation or dislocation of the patella.

A patient with "miserable malalignment syndrome" may be more susceptible to lateral subluxation of the patella. This syndrome includes a combination of internal femoral torsion and external tibial torsion which causes patellae to face in

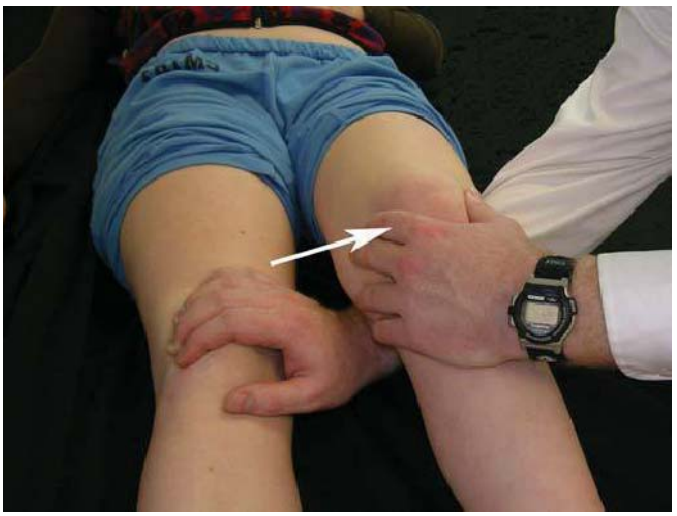

FIGURE 4-50. The patellar apprehension test is performed with the patient supine and the knee flexed to 30 degrees. The clinician gently pushes the patella laterally (*arrow*). If the patient immediately contracts her quadriceps to prevent the patella from subluxating, the test is positive.

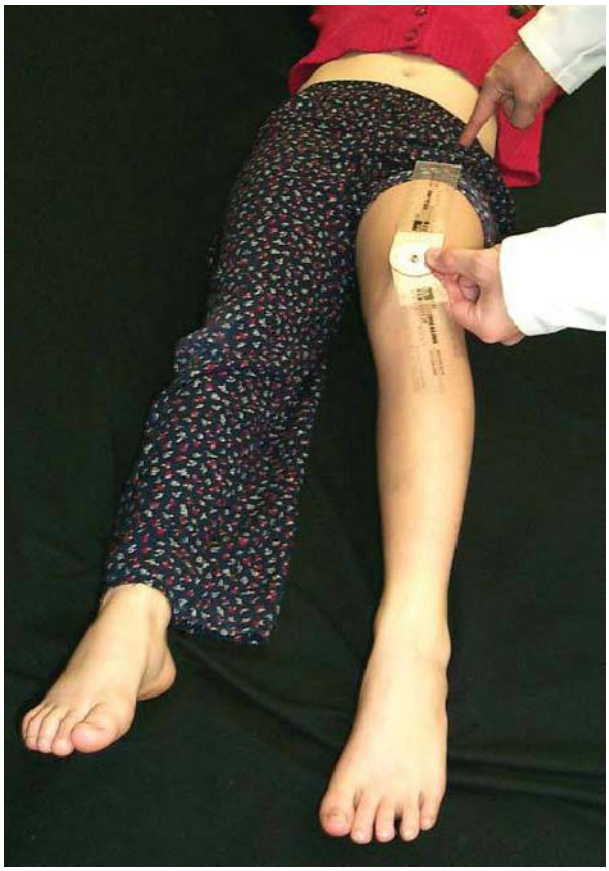

FIGURE 4-51. The Q angle is the angle formed by a line connecting the anterior superior iliac spine with the center of the patella and a second line connecting the center of the patella with the tibial tubercle. The Q angle is measured with the knee in 30 degrees of flexion, so that the patella is in contact with the femoral sulcus.

(squinting patellae) when the feet are pointing straight ahead. Patients with miserable malalignment syndrome may have knee pain and often have an increased Q angle. The Q angle is the angle formed by a line connecting the anterior superior iliac spine with the center of the patella and a second line connecting the center of the patella with the tibial tubercle (Fig. 4-51). The Q angle is measured with the knee in 30 degrees of flexion so that the patella is in contact with the femoral sulcus. Patients with an increased Q angle (>15 degrees) may have knee pain because of lateral tracking of the patella in the femoral sulcus resulting in a small contact area between the patella and femur. The maltracking can be detected by observing the patella as the patient actively extends the knee. Sitting over the side of the table with the knees flexed to 90 degrees, the patient is asked to gradually extend the knee. The patella is observed to remain in the femoral sulcus as it ascends along the axis of the femur, but as the knee reaches full extension, the patella deviates laterally like an upside-down J. This is termed a positive "J sign," and if the patient has patellofemoral instability, the patella may subluxate with this maneuver. It is important to note that a normal knee has a "J sign," but in an unstable knee it is exaggerated or occurs earlier or more dramatically compared to the normal side as the knee extends.

A patient with anterior knee pain will typically have a full range of motion from 0 to 135 degrees. The pain is often described as being circumferential around the patella, and there is usually no evidence of an effusion. A patient with Osgood-Schlatter disease will have pain over the tibial tubercle, and a patient with Sinding-Larsen-Johansson disease (jumper's knee) will have pain at the inferior pole of the patella (40). A patient with osteochondritis dissecans (OCD) will have pain elicited by direct palpation over the femoral articular surface at the site of the lesion. OCD most frequently occurs on the lateral aspect of the medial femoral condyle, but can also occur over the lateral femoral condyle, femoral sulcus, or the patella. If the lesion is in the lateral aspect of the medial femoral condyle, the pain can be reproduced by flexing the knee to 90 degrees, internally rotating the tibia, then gradually extending the knee. As the knee approaches 30 degrees of flexion, a patient with an OCD involving the medial femoral condyle will experience pain that is relieved by externally rotating the tibia. This phenomenon is termed a positive Wilson test (41).

A patient with a torn meniscus will typically have pain at the joint line. A torn meniscus can be evaluated by maximally flexing the knee and circumducting the tibia on the femur. If the clinician palpates a clunk with this maneuver, a meniscus tear is likely and this is termed a positive "McMurray test." The Apley's grinding test is another method to identify a torn meniscus. With the patient in the prone position, this test is performed by applying pressure directly to the heel, loading the knee in compression, while the tibia is internally and externally rotated. A patient with a torn meniscus will experience pain with this maneuver when the meniscus gets trapped between the tibia and the femur. A painful test is termed a positive "Apley test." The bounce test is another method to identify a torn meniscus. With the patient supine and the knee extended, the clinician elevates the foot, then drops it several inches causing the knee to hyperextend, flex, then hyperextend again. Most patients will not have discomfort with this maneuver, but if there is a torn meniscus the maneuver causes pain at the medial joint line and a reflex contraction of the hamstrings preventing the knee from hyperextending. This inability to hyperextend the knee associated with medial joint line pain is termed a positive "bounce test."

Although the patient with anterior knee pain would not typically have any abnormal ligamentous laxity, these important knee stabilizers are examined. With the patient in the supine position and the knees flexed to 90 degrees and the foot flat on the exam table, the clinician looks for a posterior sag of the tibia, which is often seen in a patient with a posterior cruciate ligament (PCL)-deficient knee. A torn PCL can be detected by the "quadriceps active test" (42). This test is performed with the patient in the supine position and the knee flexed to 90 degrees with the foot flat on the exam table. The patient is asked to slide her foot directly down the table by contracting the quadriceps muscles, while the clinician prevents the foot from moving. The force of the quadriceps muscle will

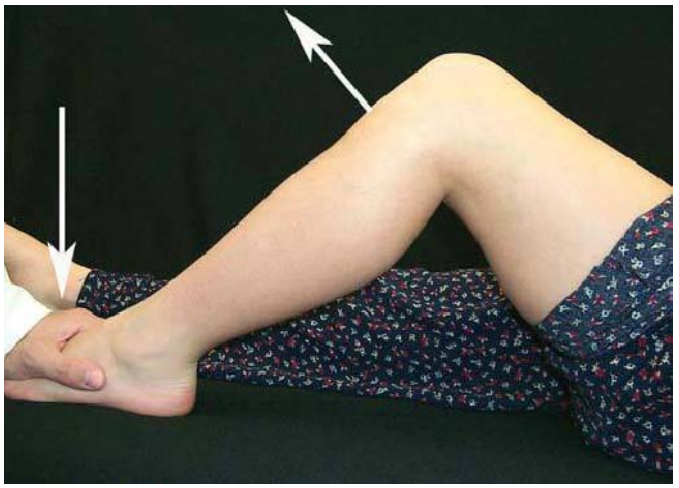

FIGURE 4-52. The quadriceps active test is performed with the patient supine and the knee flexed to 90 degrees. In this position, the tibia is subluxated posteriorly in a patient with a ruptured PCL. The patient is asked to slide her foot down the table, while the clinician prevents the foot from moving (*down arrow*). The force of the quadriceps muscle pulls the tibia anteriorly (*up arrow*), reducing the posterior subluxation.

pull the tibia anteriorly, reducing the posterior subluxation in a patient with a PCL-deficient knee (Fig. 4-52).

An anterior cruciate ligament (ACL)-deficient knee is evaluated by performing the anterior drawer test. This test is performed with the patient supine and the knee flexed to 90 degrees with the foot flat on the exam table. The foot is stabilized under the clinician's thigh, while the proximal tibia is pulled forward. The clinician should feel a solid stop after 3 to 5 mm of anterior translation of the proximal tibia on the femur, indicating an intact ACL (Fig. 4-53). It is important to palpate the hamstring tendons while performing this test, because a torn ACL may not be detected if the patient contracts the hamstring muscles during the test. A negative anterior drawer test does not always guarantee that the ACL is normal. A more sensitive test to detect a ruptured ACL is the Lachman test. This test is performed with the patient supine and the knee flexed to 30 degrees. The lateral femoral condyle is held motionless in one hand, while the tibia is pulled anteriorly with the other hand (Fig. 4-54). If anterior subluxation greater than the normal knee is detected, without a solid end point, it indicates a ruptured ACL. An ACL-deficient knee that is not painful can be detected by the pivot-shift test. This test is performed with the patient supine and the knee in extension. A valgus and internal rotation force is applied to the lateral tibia while the calcaneus is grasped with the other hand. This maneuver causes the tibia to translate anteriorly in an ACL-deficient knee. As the knee is flexed, when the iliotibial band crosses the axis of the knee joint, the tibia rapidly shifts to its normal position, and a pivot shift or jerk is felt by the clinician and the patient. This test can only be reliably performed when the patient is completely relaxed, so it is usually not helpful in an acutely injured patient.

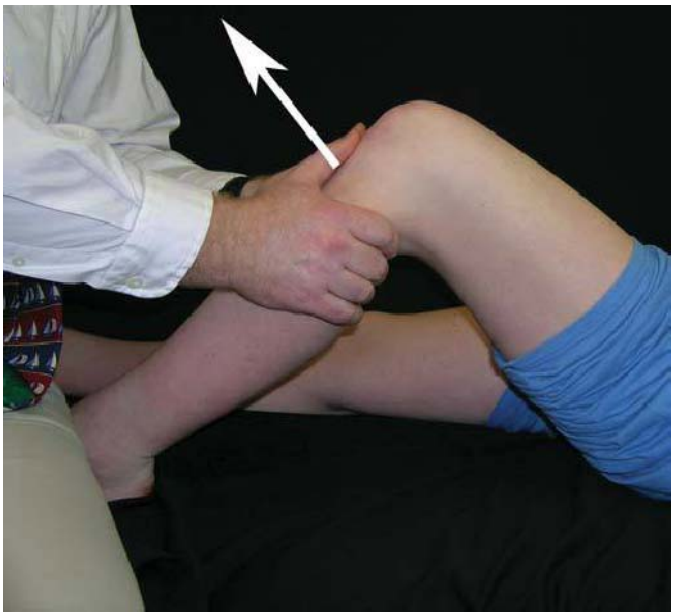

FIGURE 4-53. The anterior drawer test is performed with the patient supine and the knee flexed to 90 degrees. The foot is stabilized by the clinician's thigh, while the tibia is pulled forward at the knee (*arrow*). The clinician should feel a solid stop after 3 to 4 mm of translation, indicating an intact ACL. It is important to palpate the hamstring tendons to be sure the hamstring muscles are relaxed, because contracting hamstrings can mask an ACL-deficient knee.

The medial and lateral collateral ligaments are located just under the skin, so an injury to these ligaments is associated with pain to palpation over the ligament. By gently palpating the uninjured side and comparing it with the injured side, the

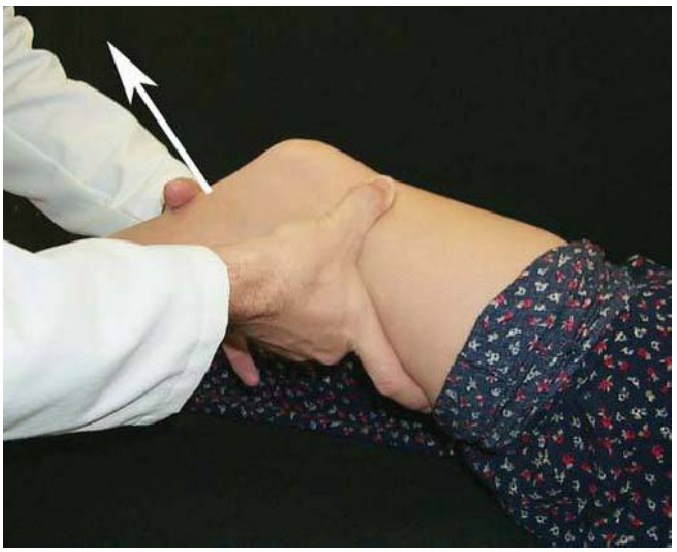

FIGURE 4-54. The Lachman test is performed with the patient supine and the knee flexed to 30 degrees. To test the left knee, the femoral condyles are held with the right hand, while the tibia is pulled anteriorly with the left hand (*arrow*). Anterior subluxation >5 mm, without a solid end point, indicates an ACL-deficient knee.

clinician can often pinpoint the location of the injury. The medial and lateral collateral ligaments are tested with the knee in 30 degrees of flexion, because varus or valgus instability can be masked by intact cruciate ligaments with the knee in extension. The medial joint line is palpated with a finger, while the examiner applies a valgus stress to the knee, and the lateral joint line is similarly palpated while the examiner applies a varus stress to the knee. The amount of joint line opening is recorded in millimeters, and 0 to 5 mm of opening with a solid end point is considered a normal amount of ligamentous laxity. Medial and lateral collateral ligament sprains are classified according to the amount of opening of the joint space on physical examination. A grade I sprain has pain over the ligament and opens 0 to 5 mm, a grade II sprain opens 6 to 10 mm, and a grade III sprain opens more than 10 mm.

This patient has anterior knee pain or patellofemoral pain secondary to a direct blow to the patella when she fell on the knee. Activity modification and physical therapy is recommended in anticipation of gradual improvement.

A 15-Year-Old Boy Is Referred for Evaluation of Bilateral Foot Pain. The patient first noted pain under the arch of his left foot 2 years ago. Six months later, he developed similar symptoms in the right foot. He describes several episodes where the left ankle gave out while walking. The last episode occurred 1 month ago, when he was walking downstairs and the left ankle gave out, causing swelling over the lateral aspect of the ankle. The swelling resolved over the next few days. The pain under both arches has worsened over the last year and is aggravated by exercise. His mother states that he has always had high arches. There is a family history of high arches in his father and paternal grandfather.

The clinician understands that pes cavus is associated with a neuromuscular disorder until proven otherwise. The most common neurologic disorder associated with pes cavus is Charcot-Marie-tooth disease. The inheritance pattern for Charcot-Marie-tooth disease is autosomal dominant, so the clinician suspects that this boy may have Charcot-Marie-tooth disease, since his father and grandfather both have high arches.

On physical examination, he ambulates with a heel-toe-gait pattern, but walks on the lateral side of the foot with the heel in varus. In standing, he has high-arched feet and points to the medial arch of both feet when describing the pain. He has painful callosities on both feet under the heels, the first and fifth metatarsals, over the dorsal surfaces of the proximal interphalangeal joints of the lateral toes. The lateral toes have moderate claw-toe deformities. A detailed motor, sensory, and reflex examination of the upper and lower extremities is within normal limits.

The longitudinal arch of each foot is elevated, shortening the medial border of the foot, creating a concave appearance. The lateral side of each foot is convex, with lengthening of the lateral border of the foot, creating a bean-shaped deformity. On both feet, the first metatarsal is plantarflexed, forcing the hindfoot to rotate into a varus position. The normal foot has a "tripod" structure with weight bearing balanced between the heel, the first metatarsal head, and the fifth metatarsal head. If the forefoot develops a pronation deformity, with plantarflexion of the first metatarsal, weight bearing will force the hindfoot into varus. The flexible hindfoot varus deformity will eventually become a structural deformity as the soft tissues of the subtalar joint contract over time. The flexibility of the hindfoot deformity is important when contemplating surgical reconstruction of a cavus foot. The forefoot contribution to the hindfoot varus deformity is determined by the Coleman block test (43). This test is performed with the patient standing with his back facing the clinician, and the amount of hindfoot varus is noted (Fig. 4-55A). A 2- to 3-cm block is placed under the lateral aspect of the foot and heel, allowing the first metatarsal to hang freely, negating any effect it may have upon the hindfoot by eliminating the tripod mechanism (Fig. 4-55B). The amount of correction of the hindfoot deformity, when standing on the block with the first metatarsal off the medial side of the block, represents the forefoot contribution to the hindfoot varus deformity. A similar test can be performed with the patient prone and the knee flexed to 90 degrees. The foot is dorsiflexed by applying pressure over the fifth metatarsal head, allowing the first metatarsal to remain plantarflexed, and the amount of correction of the hindfoot varus is observed.

These tests are crucial in preoperative planning because a flexible hindfoot will correct when the forefoot deformity is corrected, whereas a rigid hindfoot will not. This patient has pes cavus that may be associated with Charcot-Marie-tooth disease, so a referral to a geneticist is recommended. In addition, standing anteroposterior, lateral, oblique, and Harris axial radiographs of the calcaneus are recommended.

A 17-Year-Old Girl Is Referred Because She Has Pain in the Left Hip That Is Aggravated by Playing Soccer and Prolonged Sitting. She states that she first noted some discomfort in the left hip area when playing soccer on the high school team 9 months ago. Recently she has noted pain over the lateral aspect of the left hip that is aggravated by prolonged sitting and getting in and out of a car. She believes that the pain has gradually increased over the last 6 months, and she currently has a dull ache when leaning forward and often gets a sharp pain or catching sensation when turning or pivoting, especially toward the affected side. She is referred for evaluation because the pain has increased to the point where she is considering not playing soccer this year.

The differential diagnosis of hip pain in an adolescent includes avascular necrosis of the femoral head, SCFE, bursitis, tumor, hernia, infection, intra-articular loose body, lumbar spine pathology, pelvic pathology, muscle strain, early osteoarthritis, and femoroacetabular impingement (FAI). The clinician asks the patient to point to the exact location of the pain and she makes a cup with the thumb and index finger of the left hand in the shape of the letter "C," and then places her cupped hand around the anterolateral aspect of the left hip just above the greater trochanter (Fig. 4-56). This method of describing the pain is termed a positive "C sign" and is often seen in patients with FAI (44). The clinician asks if other

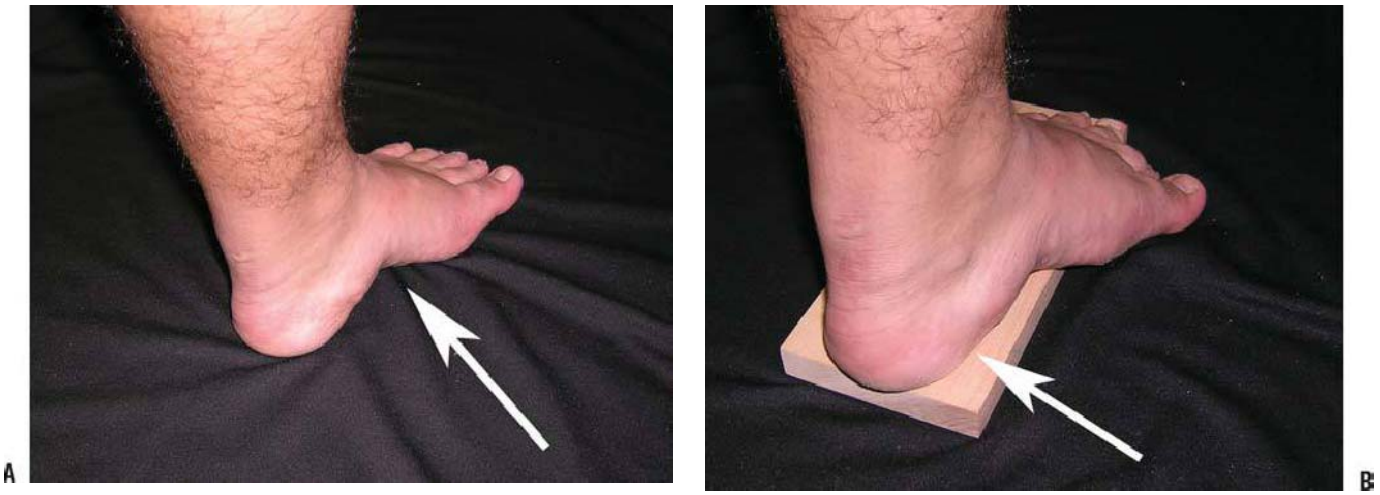

FIGURE 4-55. **A:** This foot has a pes cavus deformity with a high longitudinal arch (*arrow*), hindfoot varus, and a plantarflexed first metatarsal. **B:** The "Coleman block test" evaluates the forefoot contribution to the hindfoot varus deformity. The patient stands with the lateral aspect of the foot and heel on a 2- to 3-cm block, allowing the first metatarsal to hang freely, negating any effect it may have upon the hindfoot by eliminating the tripod mechanism. The amount of correction of the hindfoot varus deformity (*arrow*) represents the forefoot contribution to the hindfoot varus deformity.

FIGURE 4-56. In describing the pain associated with left FAI, the patient makes a cup with the thumb and index finger of the left hand in the shape of the letter "C," and then places her cupped hand over the anterolateral aspect of the hip just above the greater trochanter. This method of describing the pain is termed a positive "C sign" and is often seen in patients with FAI.

activities aggravate the pain, and the patient states that she has been noting discomfort when getting out of the car.

The physical examination often begins by asking the patient to walk in the hallway to determine if there is a limp or any asymmetry to the gait pattern, and this patient walks without a limp and a symmetric gait pattern. The examination of the hip includes inspection, palpation, and an assessment of range of motion. Inspection evaluates for asymmetry as might be seen with a limb-length discrepancy or a joint contracture secondary to pain and muscle spasm. Palpation of bony landmarks may illicit pain over the anterior inferior iliac spine indicating an avulsion injury of the rectus femoris, pain over the greater trochanter indicating a greater trochanteric bursitis, or a mass indicating a tumor. Range of motion is performed to determine if there is pain associated with any particular movement. Pain in a muscle under tension indicates a muscle strain and severe pain with any motion may indicate an infection. The patient is placed in the figure-4 position, and the FABER test is performed to determine if the patient has pain with this maneuver (Fig. 4-26). Groin pain may indicate a muscle strain involving the iliopsoas muscles, whereas pain over the sacroiliac joint may indicate sacroilitis. The flexion, adduction, and internal rotation test (FADIR test) is performed to determine if placing the hip in this position causes pain (Fig. 4-57). This test is performed with the patient supine; the clinician positions the hip in 90 degrees of flexion and maximum adduction while internally and externally rotating the hip. If pain similar to the pain the patient has been experiencing occurs with internal rotation, it may indicate FAI. In a patient with hip pain caused by

FIGURE 4-57. The flexion, adduction, and internal rotation (FADIR) test is the most sensitive test to detect FAI in a patient with groin pain. The hip is flexed to 90 degrees and adducted, while the clinician internally and externally rotates the hip. Groin pain with internal rotation, similar to the pain the patient has been experiencing, often indicates FAI.

FAI, the FADIR test is the most sensitive test to detect the FAI (44). The patient is asked to hop on the involved lower extremity to determine if hopping causes pain. Pain with hopping is of concern and may indicate a muscle strain, FAI, or stress fracture. In a patient with hip pain, it is extremely important to examine the spine, abdomen, and pelvis to evaluate for conditions that may cause referred pain to the hip such as discitis, hernia, or pelvic inflammatory disease. Finally, since some of these maneuvers can cause pain or discomfort, it is important to test the other side for comparison.

This patient has FAI, an abutment between the proximal femur and the rim of the acetabulum. The impingement typically occurs with flexion, adduction, and internal rotation of the femur. The impingement may cause labral tears and early cartilage damage that tend to gradually progress and limit her ability to exercise and play soccer. FAI is now a well-recognized cause of early osteoarthritis of the hip. Since FAI may not be detected by standard radiographs (45), a referral to an orthopaedic surgeon that specializes in hip disorders is recommended.

A 15-Year-Old Boy Is Referred for a Painful Enlarging Mass on the Back of His Left Knee. The patient is an active skateboarder who first noticed some pain and swelling on the back of the left knee several weeks ago. He cannot recall any history of trauma to the area and has recently been treated with physical therapy for patellar tendonitis. He has had no difficulty with walking or going to school, but had to quit skateboarding recently due to increasing pain. He now has pain all the time and has been taking nonsteroidal anti-inflammatory drugs (NSAIDs) to help him sleep at night. He maintains a good appetite and denies fevers, night sweats, or fatigue. His mother states that he recently had a growth spurt and grew 5 cm (2 in.) over the last 6 months. She is concerned that the mass seems to be increasing in size. His past history and family history are unremarkable.

A detailed history and physical examination is important to formulate an accurate differential diagnosis in a patient with a suspected bone lesion. The clinician understands that infections (osteomyelitis) are the most common cause of bone lesions in children. Primary bone tumors do not typically present with fever, loss of appetite, or weight loss, but they can mimic an infection with a serendipitous onset of pain, swelling, or limp with increasing lethargy. The presence of pain at the time of diagnosis is important because a painful bone lesion, or a painful lesion that subsequently develops a pathologic fracture, is often a sign of malignancy. In general, asymptomatic bone lesions that are detected as incidental findings on radiographs are usually benign lesions. Nonossifying fibromas, osteochondromas, and unicameral bone cysts are common benign lesions that are often identified incidentally on radiographs taken for other purposes.

Pain is a very important symptom when evaluating a patient with a possible tumor. It is crucial to accurately characterize the type of pain when it first occurred, how the pain has progressed, and the level of severity. Activity-related pain that is associated with benign conditions must be differentiated from more worrisome night pain and pain at rest. Although night pain can occur with a benign bone tumor, such as an osteoid osteoma, night pain is more commonly associated with malignant tumors that cause pain that insidiously progresses over time ultimately leading to severe pain that even occurs at rest.

Although the patient can frequently remember exactly when the pain first started, it is often difficult to determine how long a mass has been present. A slow-growing osteochondroma may not be noticed until just prior to the consultation, giving the patient and family a false impression that the tumor is growing quickly. Masses in the proximal femur, humerus, and pelvis may be present for several months prior to detection because of abundant soft-tissue covering.

The age of the patient is also helpful in the differential diagnosis because the most common bone lesions in children <5 years of age are eosinophilic granulomas and simple bone cysts, whereas in older children and adolescents the most

TABLE 4-6 Locations of Common Bone Tumors in Children

	Benign	Malignant
Spine		
Anterior elements	Langerhan cell histiocytosis	Ewing sarcoma Lymphoma
Posterior elements	Osteoid osteoma Osteoblastoma Osteochondroma Aneurysmal bone cyst	Metastatic neuroblastoma
Extremity		
Epiphyseal	Chondroblastoma Aneurysmal bone cyst Giant cell (adolescent)	
Metaphyseal	Osteochondroma Nonossifying fibroma	Osteosarcoma
Diaphyseal	Fibrous dysplasia Osteofibrous dysplasia Langerhan cell histiocytosis	Ewing sarcoma Lymphoma

common bone lesions are osteoblastomas, osteoid osteomas, and chondroblastomas.

Finally, the location of the tumor is extremely important as several tumors appear only in certain locations (Table 4-6). Bone tumors that occur in the posterior elements of the spine are most commonly osteoid osteomas, osteoblastomas, and aneurysmal bone cysts, whereas bone tumors that occur in the anterior elements are most commonly eosinophilic granulomas. In the appendicular skeleton, the most common epiphyseal tumors are chondroblastomas and aneurysmal bone cysts, whereas the most common diaphyseal tumors are fibrous dysplasias and eosinophilic granulomas. The most common metaphyseal tumors are nonossifying fibromas and unicameral bone cysts.

Some bone tumors, including fibrous dysplasia, enchondromas, nonossifying fibromas, and osteochondromas, may present with multiple lesions. A patient presenting with a single bony osteochondroma or exostosis should have a careful review of the family history to determine if other family members had similar bumps, suggesting the diagnosis of multiple hereditary exostosis, an autosomal dominant condition. If the physical examination detects other osteochondromas, a careful examination may detect angular deformity at wrists (ulnar deviation) and valgus deformity at the ankles secondary to tethering by the osteochondromas. In addition, these patients may have short stature and a limb-length discrepancy.

The clinician must be careful to perform a complete physical examination including inspection and palpation of the skin

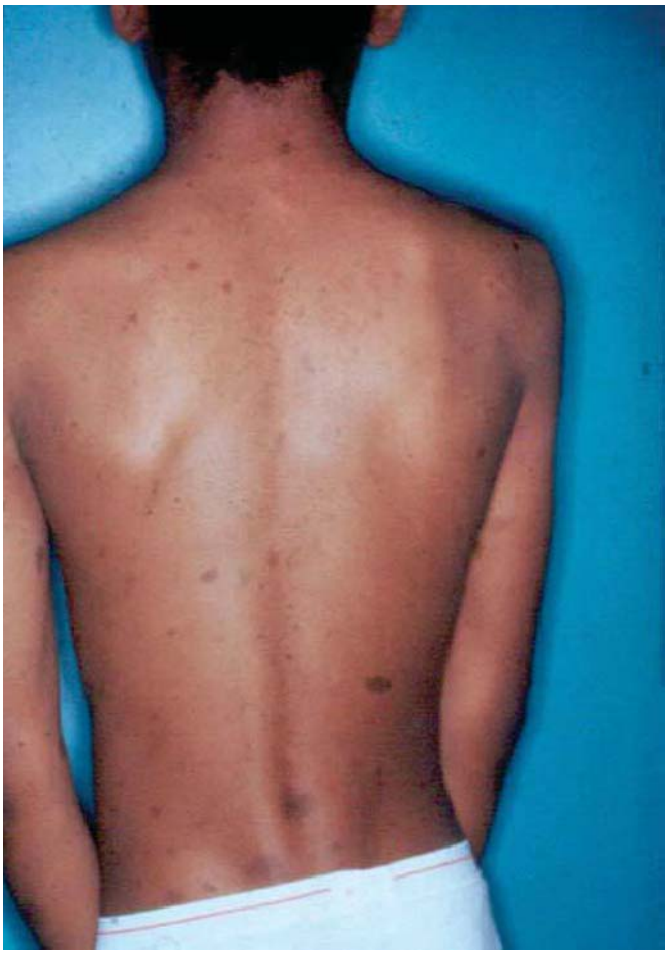

FIGURE 4-58. This boy has multiple café-au-lait spots with smooth borders like the coast of California. He has type 1 neurofibromatosis and also has numerous cutaneous neurofibromas. Most patients with type 1 neurofibromatosis will have five or more café-au-lait spots that are >1.5 cm in diameter.

and soft tissues of the upper and lower extremities. Pigmented skin lesions termed café-au-lait spots can be very helpful in the differential diagnosis. Café-au-lait spots with smooth borders (coast of California) are often seen in patients with type 1 neurofibromatosis or Jaffe-Campanacci syndrome (Fig. 4-58) (46). These patients may also have axillary freckling, and patients with type 1 neurofibromatosis will often have cutaneous neurofibromas. Most patients with type 1 neurofibromatosis will have five or more café-au-lait spots that are greater than 1.5 cm in diameter. Café-au-lait spots with rugged borders (coast of Maine) are often seen in patients with McCune-Albright syndrome (Fig. 4-59). Multiple cutaneous hemangiomas are often seen in patients with Maffuci disease. The skin is also inspected for any overlying changes such as erythema or vascular engorgement from hyperemia. These findings are often seen in association with primary bone sarcomas such as an osteosarcoma.

The bone tumor is palpated to identify a point of maximal tenderness and determine if there is an associated soft-tissue mass. Benign inactive tumors do not usually have an associated soft-tissue mass, whereas benign aggressive tumors such as

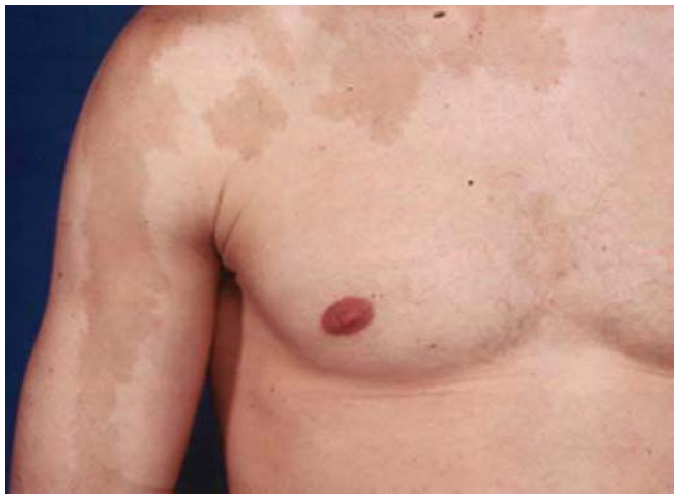

FIGURE 4-59. This boy has multiple café-au-lait spots with rugged borders like the coast of Maine. These skin lesions are often seen in patients with McCune-Albright syndrome.

chondroblastomas and eosinophilic granuloma, and malignant bone sarcomas, especially Ewing sarcoma, will often have a large soft-tissue mass. The adjacent joint is thoroughly examined to check for swelling, range of motion, and muscle atrophy to differentiate between pain secondary to the tumor and pain secondary to an intra-articular derangement.

This patient has a painful proximal tibial lesion with a large associated soft-tissue mass measuring 4 by 8 cm protruding posteromedially. These findings suggest an aggressive tumor such as an osteosarcoma, so anteroposterior and lateral radiographs of the knee are recommended.

A 13-Year-Old Boy Is Referred for Left Shoulder Pain That Is Aggravated by Swimming. He first developed pain in the left shoulder after swim practice 3 months ago. The pain is aggravated by swimming freestyle (crawl) and relieved by rest. He describes the pain as an ache in front of the left shoulder. He has never noted any swelling and he cannot recall any injury. He has been a competitive swimmer since he was 6 years old and currently practices 6 days a week. He has taken anti-inflammatory medication with some relief of his symptoms.

The clinician understands that a competitive swimmer who is having difficulty with shoulder pain will often have an overuse injury caused by extensive or improper training. If that were the case, activity modification, such as cross-training, or correction of a simple training error may resolve his symptoms. It is important to follow a patient with an overuse injury, because if the symptoms are not resolving with activity modification, it may indicate a more serious problem.

On physical examination, inspection of the shoulder reveals no muscle wasting, swelling, or deformity. Palpation reveals that he is tender over the supraspinatus tendon and the anterior aspect of the acromion. A patient with imbalance of the rotator cuff muscles may have impingement with tendonitis involving the supraspinatus tendon. Range of motion of the shoulders reveals elevation to 180 degrees bilaterally, external rotation with the arm at the side to 70 degrees bilaterally, and internal rotation to the point where the thumbs touch the spinous process of T4 on the right and T9 on the left. The limited internal rotation on the left side indicates tight posterior structures, a common finding in patients who do overhead athletics. Muscle strength testing of shoulder flexion, abduction, internal, and external rotation are graded from 0 to 5, according to the scale of the Medical Research Council (Table 4-7) (47). Rotator cuff imbalance is often seen in patients with weakness of the periscapular muscles, including the rhomboids, serratus anterior, subscapularis, and trapezius muscles.

TABLE 4-7 Grading of Muscle Strength Using the Medical Research Council Rating System

Grade	Rating	Muscle Strength	Assessment
0	Zero	No palpable contraction	Nothing
1	Trace	Muscle contracts, but no movement of bone	Trace
2	Poor	Muscle moves the bone, but not against gravity	With gravity eliminated
3	Fair	Muscle moves the bone through a full range of motion against gravity	Against gravity
4	Good	Muscle moves the bone against resistance	Near normal
5	Excellent	Normal strength against full resistance	Normal

A swimmer with shoulder pain may have ligamentous laxity with multidirectional instability, or rotator cuff tendonitis with impingement. There are several tests to detect instability and impingement. Ligamentous laxity with instability can be evaluated by palpating glenohumeral translation. With the patient seated, the clinician evaluates the amount of glenohumeral translation by stabilizing the scapula and clavicle with one hand while pushing and pulling the proximal humerus in an anterior and posterior direction with the other hand. The amount of glenohumeral translation is measured in millimeters and compared with the uninjured shoulder (Fig. 4-60). Another test for ligamentous laxity is the "sulcus sign." With the patient standing, the clinician applies a longitudinal inferior traction force on the upper extremity while palpating the distance between the humeral head and the acromion (Fig. 4-61). Excessive laxity of the superior glenohumeral ligament will allow the humeral head to subluxate inferiorly.

The apprehension test is used to evaluate for anterior shoulder instability. This test can be performed with the

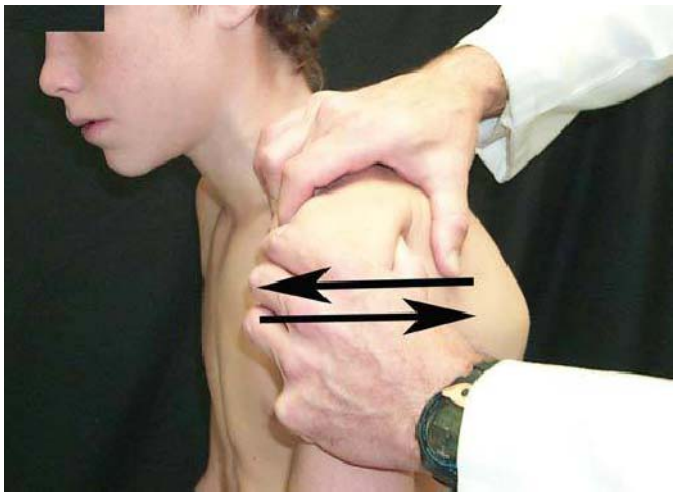

FIGURE 4-60. Ligamentous laxity of the left shoulder is evaluated with the patient seated, by holding the scapula and clavicle with the right hand while pushing the humeral head anteriorly and pulling it posteriorly with the left hand (*arrows*). The amount of glenohumeral translation is measured in millimeters and compared with the uninjured shoulder. This test is a shoulder drawer sign.

patient sitting or in the supine position. If the left shoulder is being examined, the clinician abducts the shoulder to 90 degrees and gradually increases the amount of external rotation using the left hand. The clinician's right hand is placed over the humeral head, and the clinician gently pushes the humeral head forward with the right thumb with the fingers strategically placed anteriorly to control any instability. A patient with anterior instability will experience discomfort or apprehension with this test when the humeral head subluxates anteriorly (Fig. 4-62).

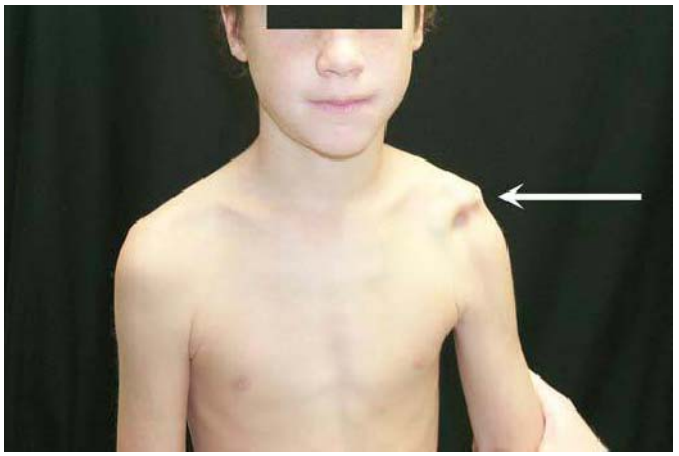

FIGURE 4-61. Ligamentous laxity of the shoulder can also be evaluated by applying a longitudinal inferior traction force to the upper extremity while observing the distance between the humeral head and the acromion (*arrow*). Excessive laxity of the superior glenohumeral ligament will allow the humeral head to subluxate inferiorly; this phenomenon is termed a "sulcus sign."

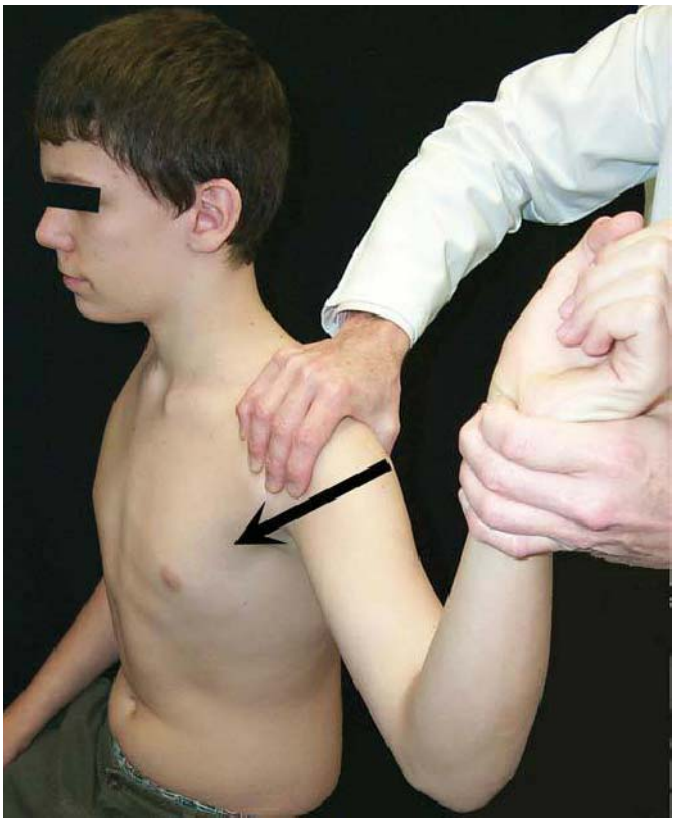

FIGURE 4-62. The apprehension test of the left shoulder is performed with the shoulder abducted to 90 degrees and externally rotated by the clinician's left hand. The clinician gently pushes the humeral head forward with the right thumb (*arrow*), while the fingers are strategically placed anteriorly in front of the humeral head, to prevent any sudden instability. Apprehension with this maneuver indicates anterior instability of the shoulder.

The relocation test can be performed with the patient sitting or supine. In the supine position, the apprehension test is performed first, and the clinician notes the amount of shoulder external rotation when the patient first experiences apprehension (Fig. 4-63A). The apprehension is relieved when the clinician pushes posteriorly on the humeral head, reducing it in the glenoid, and allowing increased external rotation of the shoulder (Fig. 4-63B). If the apprehension is relieved with this maneuver, it is termed a positive relocation test.

A swimmer with shoulder pain may have tendonitis involving the rotator cuff muscles, particularly the supraspinatus tendon. To determine if the patient has tendonitis, the clinician performs impingement tests. If the patient has tendonitis involving the supraspinatus tendon, elevation of the arm to 180 degrees, with the shoulder internally rotated, will cause discomfort as the inflamed tendon impinges against the anterior inferior acromion and coracoacromial ligament. This discomfort is termed a positive Neer impingement sign (Fig. 4-64) (48). Another method to detect impingement is to flex the shoulder forward to 90 degrees in neutral rotation, with the elbow flexed to 90 degrees. In this position, internal rotation of the shoulder by pushing down on the forearm will

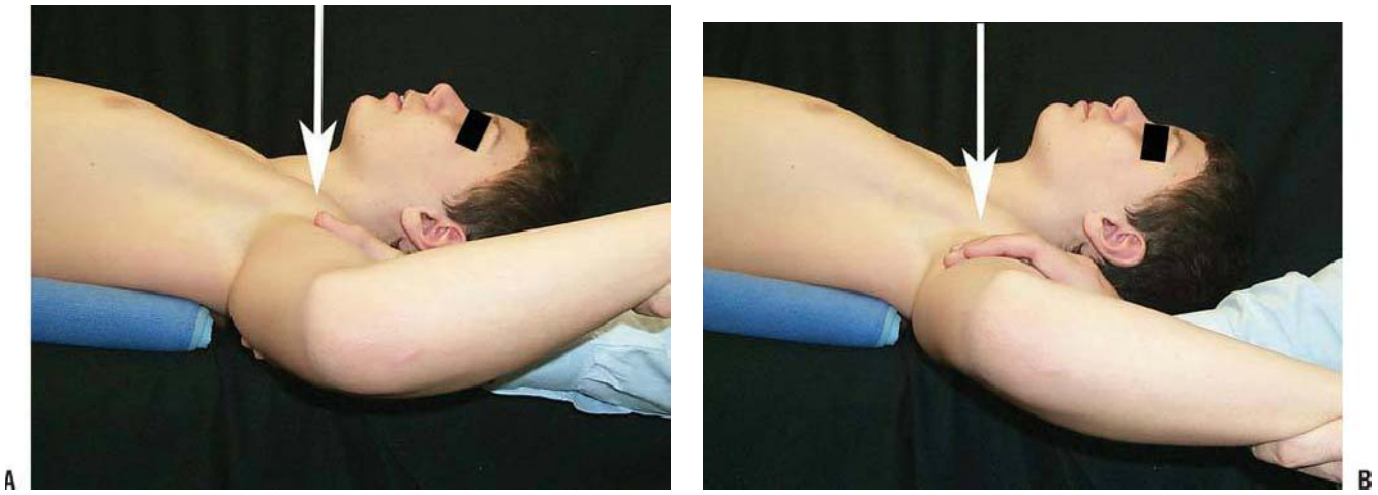

FIGURE 4-63. **A:** The relocation test is a two-part test performed with the shoulder abducted to 90 degrees. The clinician first performs an apprehension test and notes the amount of shoulder external rotation when the patient first experiences apprehension (*arrow*). **B:** The clinician then stabilizes the humeral head by pushing it posteriorly (*downward arrow*). If the patient has increased external rotation and loss of apprehension, it is a positive relocation test.

cause discomfort as the supraspinatus tendon impinges against the coracoacromial ligament. This maneuver is termed a positive Hawkins sign (Fig. 4-65) (48).

A patient with shoulder pain that is aggravated by swimming may have multidirectional instability, with an associated

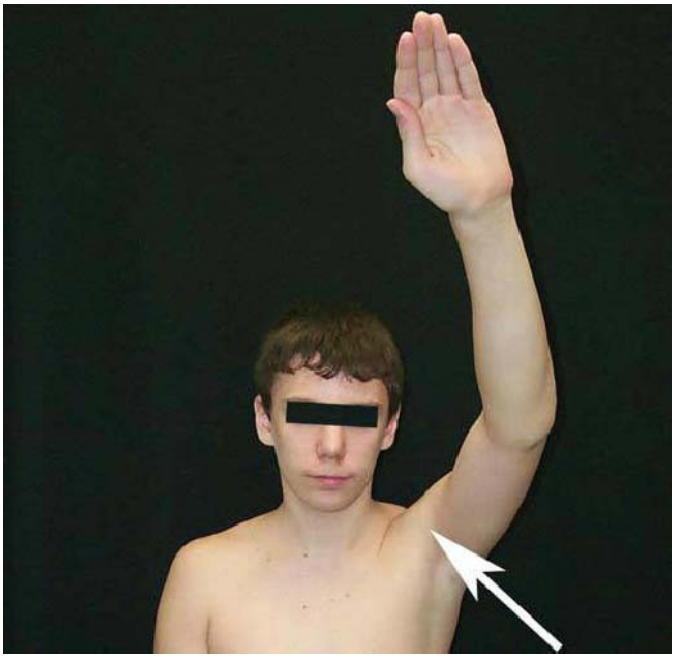

FIGURE 4-64. If the patient has tendonitis involving the supraspinatus tendon, elevation of the arm to 180 degrees with internal rotation of the shoulder will cause discomfort when the inflamed tendon impinges against the anterior inferior acromion and coracoacromial ligament (*arrow*). This is termed a positive "Neer impingement sign."

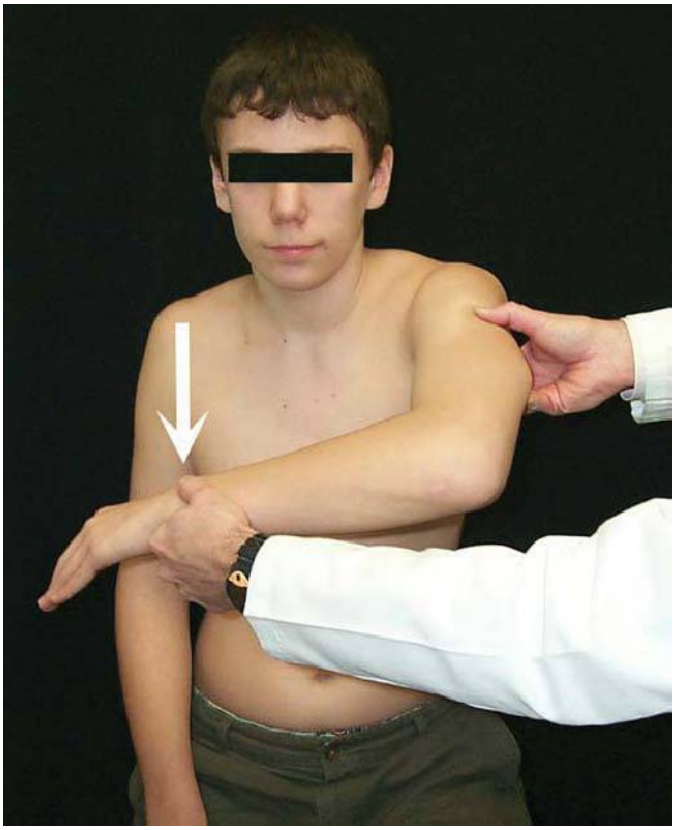

FIGURE 4-65. The Hawkins test is performed with the shoulder flexed forward to 90 degrees. While supporting the arm with one hand, the clinician then pushes down on the forearm with the other hand (*arrow*), internally rotating the shoulder. Discomfort with this maneuver indicates impingement between the inflamed supraspinatus tendon and the anterior inferior acromion and the coracoacromial ligament.

tear of the glenoid labrum. The labrum surrounds the glenoid cavity, deepening the glenohumeral joint, and the humeral head rests against the labrum. If there is a tear of the superior labrum, it is termed an SLAP (superior labrum anterior and posterior) lesion. If the labral tear involves the anteroinferior labrum, it is termed a Bankart lesion. If the attachment of the labrum to the glenoid is torn, it causes increased shoulder instability because the capsular attachment to the glenoid has been disrupted.

This patient has an overuse injury involving the rotator cuff muscles. Activity modification, in consultation with the swim coach to alter the training program, is recommended. As in any overuse injury, close follow-up is important to document that the symptoms are indeed resolving.

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