CHAPTER 3 The Orthopaedic Examination: A Comprehensive Overview

This chapter covers virtually all of the aspects of the general musculoskeletal and neuromuscular examination of the neonate, infant, child, and adolescent. Because proper function of the musculoskeletal system depends on proper functioning of the neurologic system, the boundary between orthopaedics and neurology is often blurred at the diagnostic level.

The orthopaedist is frequently the first to be consulted for clumsiness or delayed walking in a child, conditions that may be due to static encephalopathy or muscular dystrophy. Malfunction of the neurologic system can also have a significant impact on the child's developing skeletal system. For example, muscle imbalance resulting from cerebral palsy, myelomeningocele, or spinal cord injury may lead to scoliosis or dislocation of the hip joint. Thus, the pediatric orthopaedist must not only be familiar with examination of the musculoskeletal system, but also knowledgeable about the neurologic examination of the child at different developmental stages. The form used at Texas Scottish Rite Hospital for Children to record the principal findings of the initial orthopaedic examination is provided in Appendix 3–1.

Recognizing Deformities

The examiner should look for signs of musculoskeletal deformity, determine what type of deformity exists, and ascertain its exact location. If deformities exist, specific tests can help reveal them. Answers to the following questions will help accomplish this goal:

- Is the deformity in the bones, the joints, or the soft tissues?
- How severe is the deformity?
- Is the deformity fixed, or can it be passively or actively corrected?
- What factors are causing the deformity?
- Is there associated muscle spasm, local tenderness, or pain on motion?

ANGULAR DEFORMITY

The description of angular deformities should specify the site of the deformity and the position of the distal segment of the deformity relative to the proximal portion. The specific location of the deformity is denoted by its anatomic name, such as *cubitus* (elbow, forearm, ulna), *coxa* (hip), *genu* (knee), or *pes* (foot). The direction of the deformity is designated as either *valgus* or *varus,* terms that define alignment in the coronal plane.

Valgus denotes an angulation away from the midline of the body distal to the anatomic part named (i.e., the distal segment is deviated away from the midline). In cubitus valgus, the forearm is directed away from the midline, distal to the elbow. Approximately 10 to 15 degrees of cubitus valgus, or "carrying angle," is normal. In coxa valga, the angle between the femoral neck and shaft is greater than normal and the distal segment is angled away from the midline.

Varus describes an angulation toward the midline of the body distal to the anatomic part named (i.e., the distal segment is deviated toward the midline). In cubitus varus, the forearm is bent inward toward the midline of the body, distal to the elbow, while in coxa vara, the angle between the femoral neck and shaft is smaller than normal and the distal segment is angled toward the midline.

Angular deformities are measured in degrees and are most accurately recorded using a hinged goniometer. With experience, the orthopaedist may be able to accurately estimate angular measurements, but more reliable measurements are usually obtained with a goniometer.[10,69,81] However, when bony landmarks are not clear because of excess soft tissue coverage or other causes, the goniometer may give inaccurate results. If necessary, the examiner can gauge angles by visually dividing a 90-degree arc of motion into two 45-degree segments or three 30-degree segments and projecting the observed angle into these arcs. The affected limb should always be compared with the contralateral extremity.

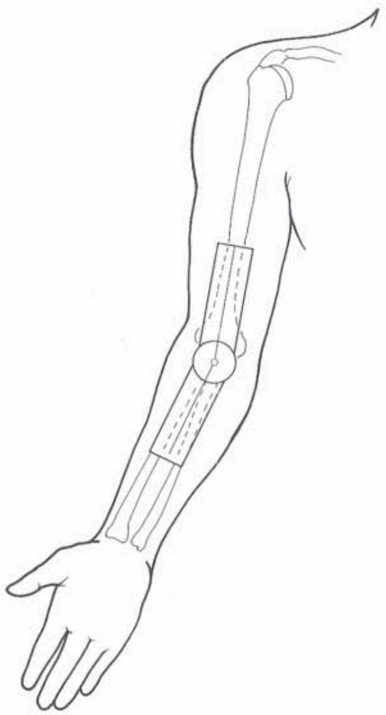


FIGURE 3–1 Measurement of the carrying angle of the elbow joint (cubitus valgus). (Reproduced from Greene WB, Heckman JD: The Clinical Measurement of Joint Motion. Rosemont, IL, American Academy of Orthopaedic Surgeons, 1994.)

The degree of cubitus valgus, or carrying angle, of the elbow is measured with the elbow at the zero starting position (i.e., with the elbow fully extended and at zero degrees of flexion).[2,3] The goniometer is positioned on the volar surface of the arm and aligned with the midaxis of the humerus and the midaxis of the forearm (Fig. 3–1).[30] Beals measured the mean carrying angle in a radiographic study conducted on 422 patients.[7] Patients were divided into four age groups: newborn through 4 years of age, 5 through 11 years, 12 through 15 years, and adults, with approximately 50 males and 50 females in each group. The mean carrying angle was 15 degrees in the newborn to 4-year-old group and increased slightly with age to 17.8 degrees in adults. There was no difference by sex of the subject.

Knee joint alignment is measured with the patient standing with the knee fully extended. The goniometer is aligned with the midaxis of the distal femur and proximal tibia (the anatomic axis of the knee) (Fig. 3–2). For most clinical evaluations, this measurement is sufficient; however, for hip surgery and lower extremity realigning, preoperative assessment of the axis of the hip, knee, and ankle (the mechanical axis) should be done using full-length weight-bearing radiographs. Normal knee alignment, as measured by the femoral-tibial angle, changes as a child grows older. Neonates usually have 10 to 15 degrees of varus angulation, which evolves to a neutral femoral-tibial alignment between 14 and 22 months of age, to a maximum valgus of 10 to 15 degrees by 3 to $3\frac{1}{2}$ years of age.[23,70] This is followed by a gradual decrease in valgus, with normal mature alignment of 5 to 7 degrees of femoral-tibial angle realized by 6 to 8 years of age.

Other objective methods of measurement can be used for specific situations. The degree of *genu valgum* (knock-knees) can be determined by measuring the distance between the medial malleoli when the knees are fully extended, the patellae are facing exactly upward, and the medial femoral condyles are brought together with moderately firm pressure to compress excessive subcutaneous fat. The degree of genu valgum can also be determined by measuring the angle between the lateral surface of the thigh and leg. The clinical appearance of knock-knees is exaggerated when there is excessive subcutaneous fat on the thigh or atrophy of the calf (especially of the medial head of the gastrocnemius). The degree of *genu varum* (bowlegs) can be similarly determined by bringing the medial malleoli together, firmly compressing them, and measuring the distance between the medial femoral condyles. The patellae must be facing exactly forward, as medial rotation of the lower extremities at the hips will result in the appearance of bowlegs.

CONTRACTURES

Contractures result from fibrosis of the tissues supporting the muscles or joints or from muscle fiber disorders, either of which cause fixed resistance to passive stretch of a muscle. There is a shortening and loss of flexibility of muscles, joints, tendons, or fascia. Contractures can be either congenital or acquired. Examples of congenital contractures include congenital muscular torticollis, abduction contracture of the hip, and multiple pterygium syndrome. Children with spina bifida often have a capsular contracture in the posterior knee capsule.

Acquired contractures of joints may be caused by muscle

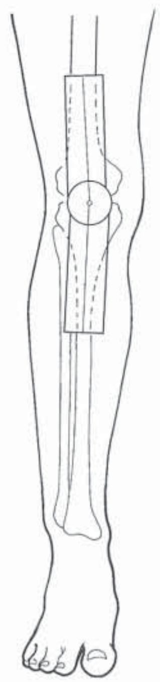


FIGURE 3–2 Measurement of the standing femoral-tibial angle at the knee. (Reproduced from Greene WB, Heckman JD: The Clinical Measurement of Joint Motion. Rosemont, IL, American Academy of Orthopaedic Surgeons, 1994.)

imbalance (as seen with cerebral palsy), inflammatory arthritis, muscle injury, periarticular trauma, or idiopathic conditions (e.g., Morphea syndrome[54]). A tight iliopsoas muscle in a child with cerebral palsy or myelomeningocele may cause a hip flexion contracture. Flexion contracture of the knee may be caused by a displaced torn meniscus that impedes extension of the joint. Synovial fluid collection secondary to juvenile arthritis may block normal joint motion. Forearm ischemia from a compartment syndrome results in Volkmann's contracture, which is characterized by pronation and flexion of the hand, shrinkage and hardening of the forearm muscles, and loss of muscle power. Muscle or joint contractures can also occur postoperatively if the patient does not perform appropriate strengthening and range-of-motion (ROM) exercises. Gastrocnemius contracture can occur if the ankle is immobilized with the foot in equinus.

Evaluating contractures is an important part of the pediatric orthopaedic examination. Neonates have physiologic contractures of upper and lower limbs.[15,25,64,66,82] In infants and younger children, contracture assessment primarily focuses on the lower extremities, whereas in older children, particularly those who participate in throwing sports, it is important to also inspect the upper extremity (i.e., the elbow and shoulder). When assessing two-joint muscles (e.g., hamstrings, gastrocnemius) for contracture, the examiner needs to restrict the movement of one joint before testing the second joint. For example, when examining for hamstring contracture, the femur should first be flexed and stabilized on the pelvis, and the knee then extended.

SPASTICITY

Spasticity refers to an abnormal increase in muscle tone (excessive muscle tension) that interferes with muscle relaxation, impedes normal joint ROM, and causes stiff and awkward movements. Spasticity can result from upper motor neuron injury, with cerebral palsy the most common cause. During the physical examination, the degree of actual spasticity in a particular muscle can change significantly depending on numerous factors, including patient anxiety, room temperature, and time of day.

It is more difficult to put certain joints through passive ROM when a patient has spastic muscles (e.g., extension of the knee joint when the hamstrings are spastic). However, with gentle persuasion by the examiner, the spastic muscle usually will relax and greater joint motion can be attained. Changes in patient body position can also affect ROM. Because of this, measurements of the same parameter may vary during the examination. A review by Perry[63] showed that ankle dorsiflexion decreased as patients went from the supine position to sitting to standing. In 95 percent of cerebral palsy patients, flexion of the knee permitted greater ankle dorsiflexion. To accommodate this variability, the examiner should note at what degree initial resistance is encountered and the total ROM attained with persuasion. The reliability of goniometric measurements in determining joint motion in patients with spasticity is debatable.[4,32]

The examiner should also describe the general muscle tone of the patient, characteristics of the resistance (e.g., persistent initial resistance with ensuing relaxation, constant fixed resistance), and the position of adjacent joints (e.g., whether the hip or knee was flexed or extended, or the foot was neutral or supinated, when testing ankle dorsiflexion). For example, one might record that the ankle has 10 degrees of dorsiflexion with the knee extended.

Joint Range of Motion

Measuring joint ROM provides important information regarding orthopaedic diseases and disorders and the results of treatment. The effect of acute illness or injury on joint motion can help in the diagnosis. For example, both transient synovitis and septic arthritis of the hip will reduce joint mobility, but the loss of motion will be much greater in the infected joint. Improvement in joint motion during treatment for septic arthritis indicates that the hip is responding to therapy. The extent and type of injury to a joint during athletic competition can be determined to some degree by how much joint mobility is lost. A return to normal joint motion is an important factor in deciding when an athlete is ready to return to competition.

During the physical examination, joint motion can be measured actively, whereby the patient moves the limb, or it can be measured passively, whereby the examiner moves the patient's limb. Active and passive ROM will often differ when disease or injury to a joint renders the patient incapable of completing full ROM against gravity. When this occurs, both arcs of motion should be recorded. The examiner should also compare the motion of the affected extremity with that of the normal, contralateral one, because joint mobility is normally the same on the right and the left sides.[9,10,34,49,58,67,77]

Joint motion is most accurately measured with a goniometer,[81] particularly at the elbow, wrist, finger, knee, and ankle joints. Because overlying soft tissue at the shoulder and hip obscures bony landmarks, it is more difficult to obtain consistent alignment of the goniometer at these joints. To measure an extended extremity, one arm of the goniometer is aligned with the axis of the proximal segment and the other arm is aligned with the axis of the distal extremity. The zero-degree mark is positioned on the distal segment.

TABLE 3–1 **Description of Joint Motions**

Flexion: Act of bending a joint; a motion away from the zero starting position.
Extension: Act of straightening a joint; a return motion to the zero starting position.
Hyperextension: When the motion opposite to flexion is an extreme or abnormal extension (as may be seen with the knee or elbow joint), and the joint extends beyond the zero starting position.
Abduction: Lateral movement of the limbs away from the median plane of the body, or lateral bending of the head or trunk.
Adduction: Movement of a limb toward the median plane of the body.
Supination: Act of turning the forearm or hand so that the palm of the hand faces upward or toward the anterior surface of the body.
Pronation: Turning of the palm of the hand so that it faces downward or toward the posterior surface of the body.
Inversion: An inward turning motion (seen primarily in the subtalar joint of the foot).
Eversion: An outward turning motion.
Internal (inward) rotation: Process of turning on an axis toward the body.
External (outward) rotation: Process of turning on an axis away from the body (opposite motion of internal rotation).

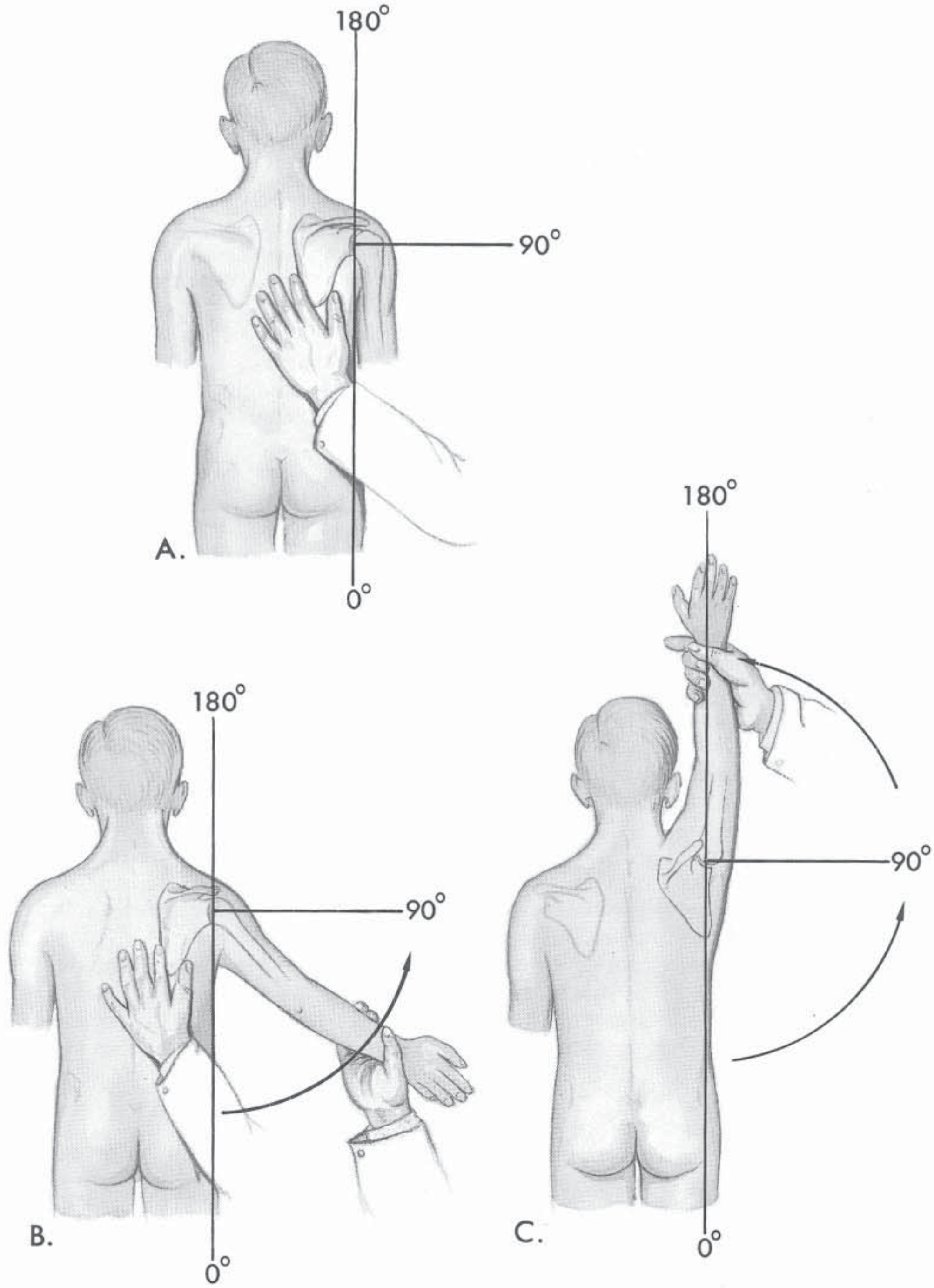


FIGURE 3–3 Total shoulder motion is a combination of scapulothoracic and glenohumeral movement. Stabilizing the scapula (**A**) allows the examiner to assess glenohumeral motion (**B**). Leaving the scapula free allows the examiner to assess total shoulder motion (**C**). Scapulothoracic motion is responsible for the difference between the motion measured in B and C. (Adapted from Committee for the Study of Joint Motion (eds): Joint Motion: Method of Measuring and Recording. Chicago, IL, American Academy of Orthopaedic Surgeons, 1965.)

The proximal end of the goniometer is held in place while the joint is moved and the distal arm of the goniometer rotated. At completion of the movement, the degree of joint ROM is recorded from the goniometer.[30]

Motion is measured in degrees of a circle with the joint as its center.[12] The degrees of motion of a joint are added in the direction in which the joint moves from the anatomic zero starting position. To ensure conformity when measuring joint ROM, the extended anatomic position of a limb is designated as being zero degrees (rather than 180 degrees).[30] Thus, when a fully extended extremity joint is bent from the anatomic zero position to a right angle, the range of motion is 90 degrees of flexion. The different joint motions are described in Table 3–1.

Normal joint ROM will vary among persons based on age and sex. Neonates typically have (1) decreased abduction

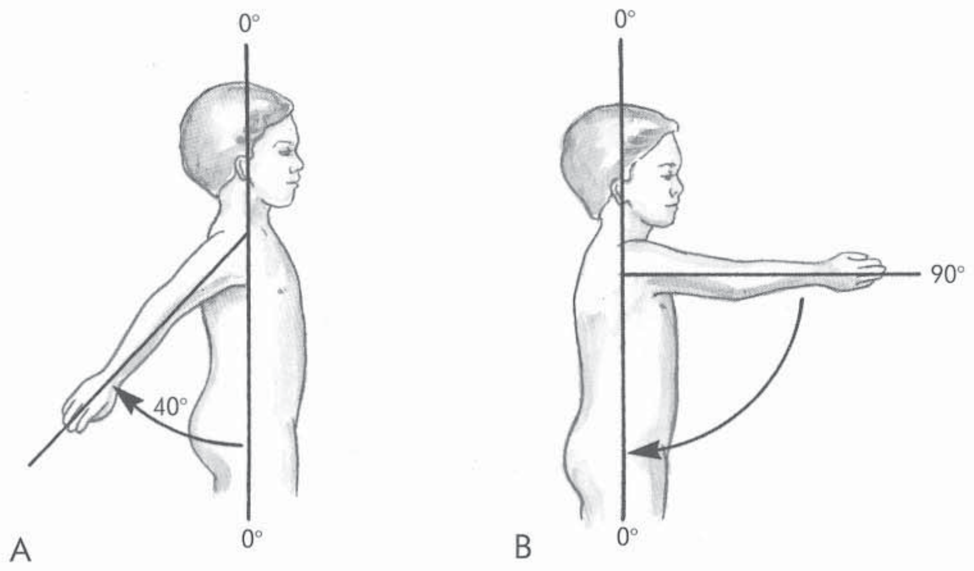


FIGURE 3–4 Extension (backward motion) (A) and flexion (forward motion) (B) of the shoulder in the sagittal plane.

of the shoulder, (2) greater external rotation and limited internal rotation of the hip, (3) greater dorsiflexion and limited plantar flexion of the ankle, and (4) flexion contractures at the elbow, hip, and knee.[25,35] By 3 months of age a child will usually exhibit an adult arc of motion at all joints except the hip.[35] The hip joint continues to show an increase in external rotation and a decrease in internal rotation until the child is 8 to 24 months old.[15,35,76] Joint ROM is greater in children than in adults because children have greater joint laxity.[6,13,77,86] Children also have greater inversion and dorsiflexion of the foot and ankle than adults. As a person gets older, connective tissue becomes progressively more rigid, particularly in and around muscles and tendons, resulting in decreased joint ROM.[6] Because of greater ligamentous laxity, females have greater ROM than males in some joints,[18,49] but not in all joints or in all planes of motion.[49,58,68]

THE SHOULDER

The shoulder has the greatest ROM of any joint in the body, allowing myriad positions and planes of motion.[33] Shoulder motion is divided into true glenohumeral motion, pure scapulothoracic motion, and combined glenohumeral and scapulothoracic motion (Fig. 3–3). Maximum shoulder motion normally is a combined movement rather than motion in a single plane.[30] For example, to achieve maximum elevation (flexion), there must be a combination of slight external rotation and abduction.[11] *Extension* (backward motion) and *flexion* (forward motion) of the shoulder occur in the sagittal plane (Fig. 3–4). *Abduction* and *adduction* of the shoulder occur only in the horizontal plane from the midsagittal zero position of the body (Fig. 3–5). Abduction is motion of the arm *away* from the midsagittal axis of the body, adduction is movement of the arm *toward* the axis.

During the physical examination, shoulder motion is assessed with the patient standing. However, if the examiner cannot control spine and pelvic motion, the patient should be supine when external rotation and elevation are measured.

The term *elevation* (i.e., flexion) is used to define all upward motions of the humerus in any plane—that is, motions entailing the vertical raising of the arms in any position of the horizontal plane of abduction or adduction (see Fig. 3–4B).[33] The zero starting position is with the arm at the side of the body. When assessing range of elevation of the glenohumeral joint, the examiner stands behind the patient and immobilizes the scapula by holding its inferior angle (see Fig. 3–3A). Scapulothoracic joint motion can be further restricted by firmly placing a hand over the acromion of the upper limb being tested. In combined glenohumeral and scapulothoracic motion, the scapula rotates upward and forward over the chest wall, allowing the shoulder to elevate to 180 degrees (see Figs. 3–3B and C).

When the shoulder is elevated, the first 20 degrees of motion represents pure glenohumeral joint motion, and the scapula does not move (Fig. 3–6A). After this point, continued elevation of the arm results in combined movement

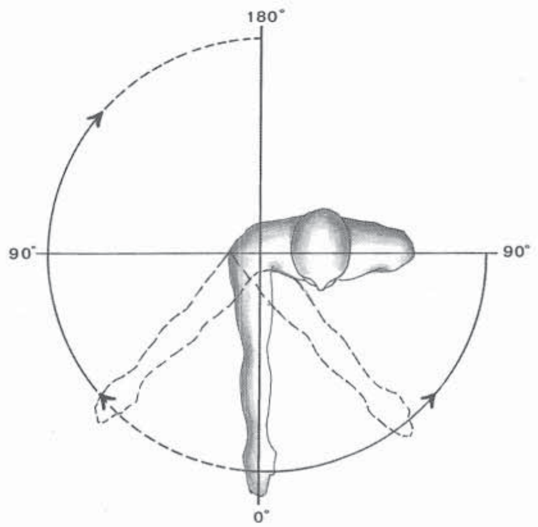


FIGURE 3–5 Abduction and adduction of the shoulder in the horizontal plane from the midsagittal zero position of the body.

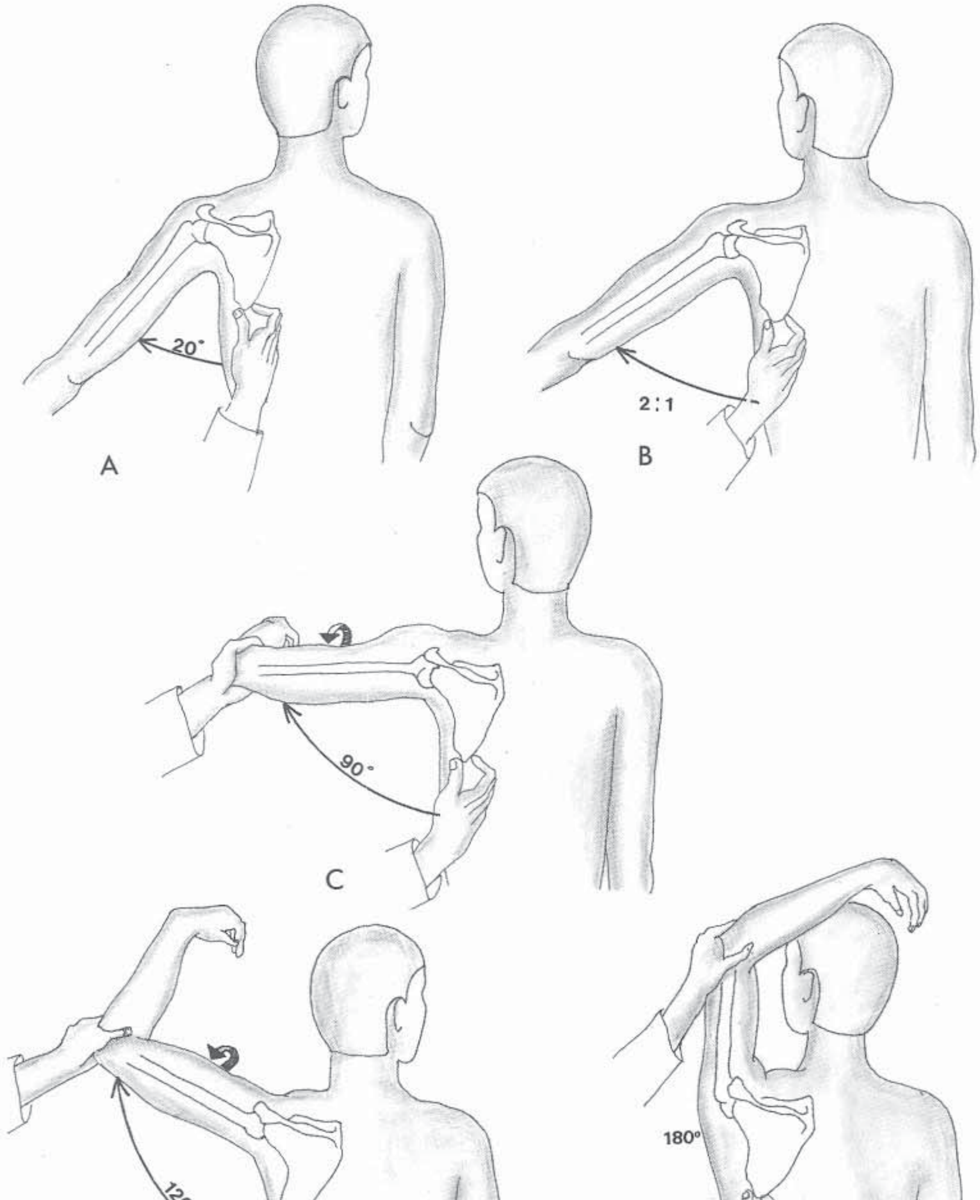


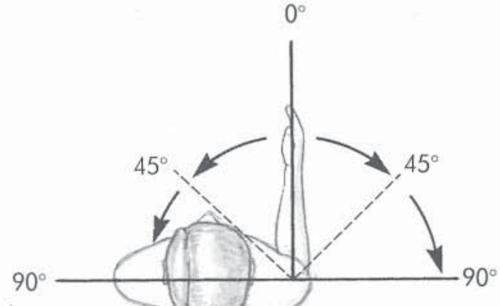
FIGURE 3–6 **A,** When the shoulder is elevated, the first 20 degrees of movement represents pure glenohumeral joint motion; the scapula does not move. **B,** From this point, continued elevation of the arm results in combined movement of the glenohumeral and scapulothoracic articulations in a 2:1 ratio. **C,** When the scapula is immobilized, pure glenohumeral elevation is about 90 degrees. **D,** At about 120 degrees of combined shoulder elevation, the surgical neck of the humerus abuts the acromion process. **E,** Complete elevation of the shoulder (i.e., 180 degrees) is a combined glenohumeral and scapulothoracic movement and is made possible by external rotation of the shoulder, which turns the surgical neck of the humerus away from the tip of the acromion and increases the articular surface of the humeral head.

of the glenohumeral and scapulothoracic articulations in a 2:1 ratio (i.e., for every 3 degrees of total shoulder elevation, 2 degrees of elevation represents motion of the glenohumeral joint and 1 degree of elevation comes from the scapulothoracic joint) (Fig. 3–6B).[26] When the scapula is immobilized, pure glenohumeral elevation is about 90 degrees (Fig. 3–6C). At about 120 degrees of combined shoulder elevation, the surgical neck of the humerus abuts the acromion process (Fig. 3–6D). Complete elevation of the shoulder (i.e., 180 degrees) is a combined glenohumeral and scapulothoracic movement and is made possible by external rotation of the shoulder, which turns the surgical neck of the humerus away from the tip of the acromion and increases the articular surface of the humeral head (Fig. 3–6E).

Shoulder *extension* (posterior elevation) is motion of the extended arm in the opposite direction from that of forward elevation (see Fig. 3–4A). For maximum extension, the shoulder must rotate internally.[11] Normally, the shoulder is able to extend 45 to 55 degrees.

Internal and *external* shoulder *rotation* are assessed with the patient's arm in the neutral position and the examiner standing in front of the patient. The patient's elbow must be at the side of the body and flexed 90 degrees to prevent substitution of adduction for external shoulder rotation and abduction for internal shoulder rotation. The forearm, which is parallel to the sagittal plane of the body, is rotated internally toward the sagittal axis of the body and externally away from the body. The shoulder is the axis and the forearm is the indicator of motion (Fig. 3–7A). The normal range of internal shoulder rotation is 50 to 60 degrees (the chest wall blocks its motion), and the normal range of external shoulder rotation is 40 to 45 degrees.

Shoulder rotation may also be assessed with the neutral zero position of the shoulder at 90 degrees of elevation and 90 degrees of abduction and with the forearm parallel to the floor (Fig. 3–7B). In internal rotation, the arm is moved inferiorly toward the floor, with the average internal rotation approximately 70 degrees. Restricted internal rotation in this position may be due to shoulder instability.[29] In external rotation, the shoulder is moved superiorly toward the ceiling, with the average external rotation approximately 100 degrees.



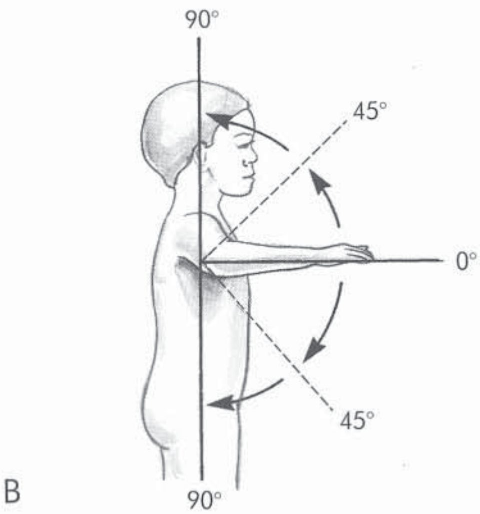


FIGURE 3–7 **A,** Internal and external rotation of the shoulder measured with the arm at the side of the body. Normal range of internal rotation is 50 to 60 degrees; normal range of external rotation is 40 to 45 degrees. **B,** Internal and external rotation measured with the shoulder in neutral zero position at 90 degrees of elevation and 90 degrees of abduction (i.e., the forearm is parallel to the floor). Internal rotation moves the arm inferiorly toward the floor; external rotation moves the shoulder superiorly toward the ceiling.

There are a number of quick and easy methods of clinically assessing active shoulder ROMs. To measure shoulder elevation, the patient should stand with elbows straight and forearms fully supinated, and then raise both arms vertically and touch the fingers over the head (Fig. 3–8A). To measure horizontal abduction and external rotation, the patient should place both hands behind the neck and push the elbows posteriorly (Fig. 3–8B). Adduction and internal rotation are measured by having the patient reach across the chest and touch the opposite shoulder (Fig. 3–8C). Extension, internal rotation, and adduction are tested by having the patient reach behind the back and touch the lower angle of the opposite scapula (Fig. 3–8D). Elevation, internal rotation, and adduction are tested by having patient reach behind the head and neck and touch the upper angle of the opposite scapula (Fig. 3–8E). Finally, having the patient reach behind the back and touch the opposite buttock allows the examiner to measure extension, adduction, and internal rotation (Fig. 3–8F).

THE ELBOW

The elbow is a typical *hinge* joint in which there is only one freedom-of-motion plane. Although there are three sites of movement—the ulnohumeral, radiohumeral, and radioulnar articulations—elbow motion is centered at the ulnohumeral joint,[3] and the description of motion is typically limited to the flexion-extension plane.[14]

The zero starting position is with the elbow fully extended and straight (zero degrees) and the arm in supination. The normal elbow ROMs are from zero to 150 degrees of *flexion* and from 150 degrees (the angle of maximum flexion) to zero degrees of *extension* (the zero starting position) (Fig. 3–9A). *Hyperextension,* measured as degrees by which the joint extends beyond the zero starting position, varies from 5 to 15 degrees.[13,86] Hyperextension is not seen in all individuals. Restricted elbow ROM may be described, for example, as flexion from 30 to 90 degrees, or a joint that has a flexion deformity of 30 degrees with further flexion to 90 degrees (Fig. 3–9B).

THE FOREARM

Rotation of the forearm is a combined motion of the proximal and distal radioulnar joints and the radiohumeral joint.[2] The planes of motion are *pronation* (turning of the palm backward or posteriorly: the palm faces down) and *supination* (turning of the palm forward or anteriorly: the palm faces up) (Fig. 3–10). To assess forearm rotation, the humerus is stabilized against the torso (to prevent any compensating adduction and abduction motion by the humerus to augment pronation and supination), and the elbow is flexed to 90 degrees.[17] The zero starting position is with the extended thumb aligned with the humerus.[30] To better evaluate the degree of pronation and supination, the examiner should palpate the radial and ulnar styloid as the forearm is being rotated. Having the patient hold a pencil or similar object in the palms with flexed fingers can make it easier to discern forearm rotation. Normal range of pronation is 70 to 80 degrees, and normal range of supination is 80 to 90 degrees.[9,72,80]

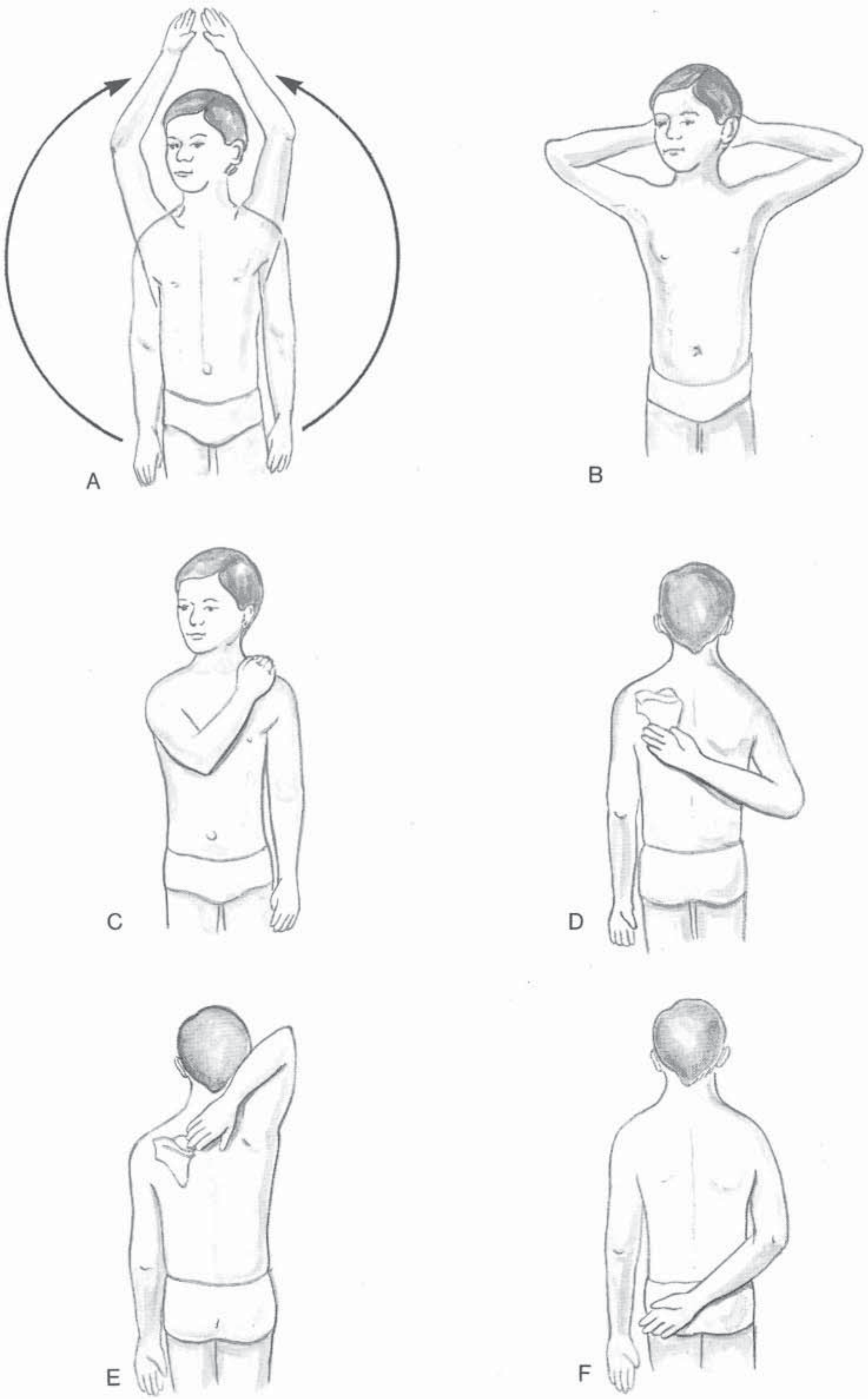


FIGURE 3–8 Quick method of clinically assessing active shoulder range of motions. **A,** Elevation of both shoulders. **B,** Horizontal abduction and external rotation. **C,** Adduction and internal rotation. **D,** Extension, internal rotation, and adduction. **E,** Elevation, internal rotation, and adduction. **F,** Extension, adduction, and internal rotation.

THE CERVICAL SPINE

The cervical spine is the most flexible part of the vertebral column. There are goniometers specific for measuring cervical spine motion; however, standard goniometers are just as accurate.[87] Visual evaluation of cervical spine motion is not as reliable as goniometric measurement. The ROMs evaluated are flexion, extension, right and left lateral bending, and right and left rotation.

Normally, opposite movements (e.g., flexion/extension, right/left bending, right/left rotation) are nearly equal.[30,41] However, the ROM in particular planes varies at different vertebral levels (Table 3–2).[1,20,41,61,62] Parameters for cervical spine mobility based on the age of the patient are provided

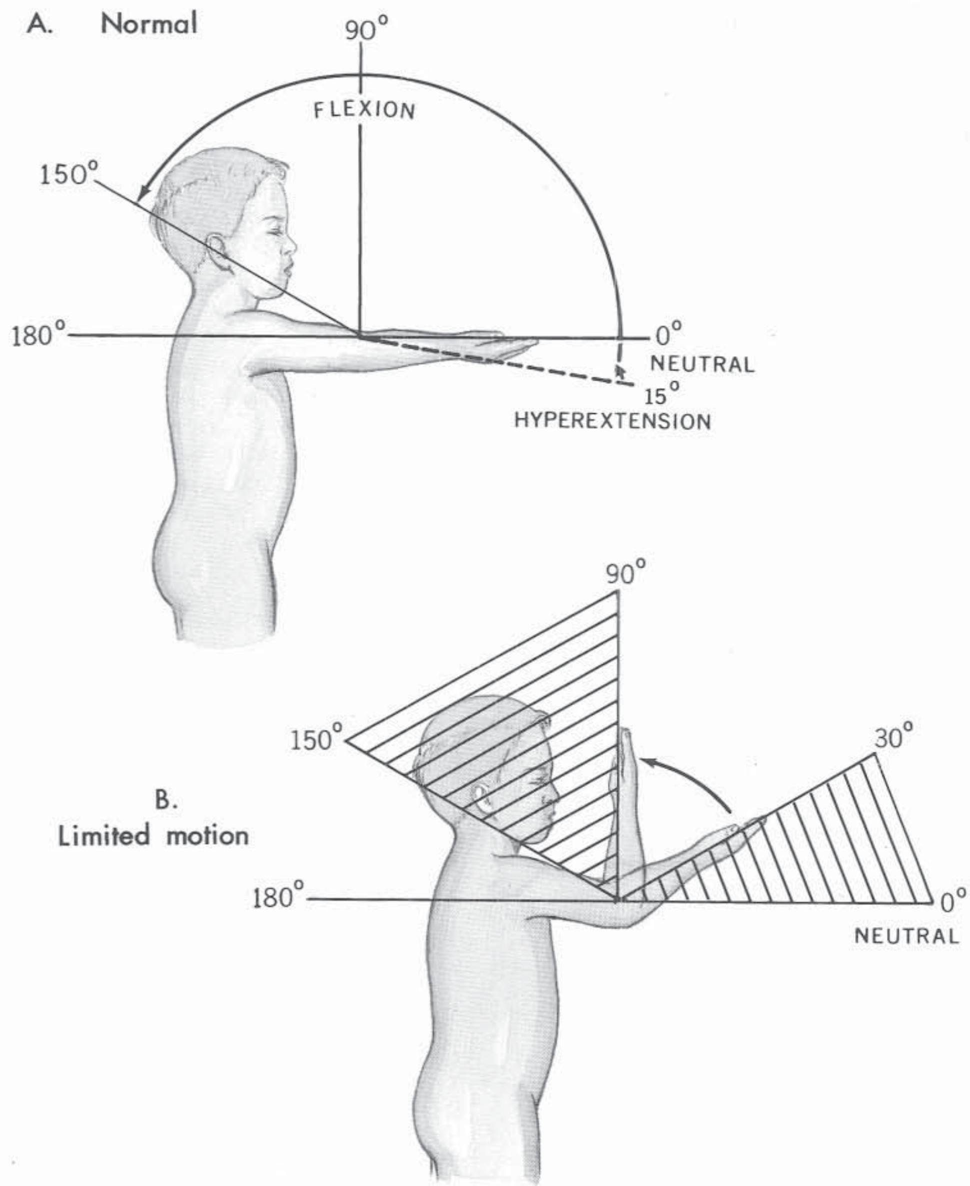


FIGURE 3–9 **A,** Normal arc of elbow flexion and extension. In the zero starting position the elbow is fully extended and straight (zero degrees), and the forearm is supinated. **B,** Examples of limited arcs of elbow motion.

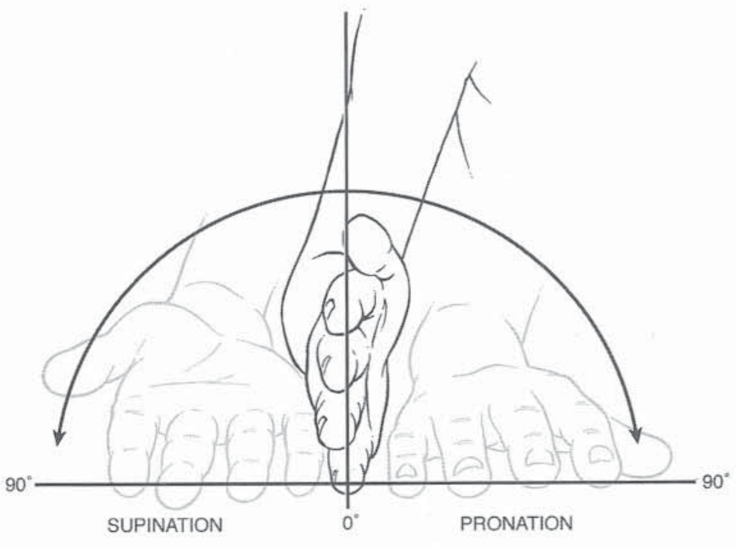


FIGURE 3–10 Supination is turning of the palm forward or anteriorly, such that the palm faces up. Pronation is turning of the palm backward or posteriorly, such that the palm faces down.

TABLE 3–2 **Cervical Range of Motion at Different Vertebral Levels**

Occiput–C1 joint: Substantially greater extension than flexion
C1 to C6: Flexion and extension approximately equal
Lower cervical segments: Flexion/extension greater, with maximum movement at C5–6 vertebral level
C6 to T1: Flexion greater than extension, particularly at C7–T1 joint

TABLE 3–4 **Movement of the Vertebrae at Various Levels of the Cervical Spine**

C1–2: 55% to 60% of rotation occurs at this level.
Occiput to C5: Flexion is coupled with rotation.
C5 to C7: Extension is combined with rotation.
Upper cervical spine: Lateral bending goes in opposite direction of rotation.
Lower cervical spine: Bending goes in same direction as rotation.

in Table 3–3.[34] Table 3–4 shows the movement of the vertebrae at the various levels of the cervical spine.[30,55] A more extensive discussion of the various range of motions of the cervical spine can be found in *The Cervical Spine,* by the Cervical Spine Research Society.[39]

Although goniometric measurement is more accurate, clinical evaluation is usually performed by visual assessment, with the patient's nose and chin used as midline landmarks. Inclinometers may also be used during an examination. The tool is accurate in measuring flexion/extension and lateral bending, but not as reliable for rotation.[1]

The zero starting position for measuring *flexion/extension* motion is with the neck aligned with the trunk (Fig. 3–11). The examiner should stabilize the trunk during the movements so that thoracic spine motion does not come into

TABLE 3–3 **Radiographic Cervical Spine Mobility in 160 Patients Aged 1–16 (10 Patients per Year of Age)**

	Age (yr)																Total (1–16 yr)		Total (1–7 yr)	
Displacement/Mobility	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*No.*	*(%)*	*No.*	*(%)*
Anterior displacement C2–3 (marked)	4	1	3	1	2	2	0	0	1	1	0	0	0	0	0	0	15	(9)	13	(19)
Anterior displacement C2–3 (moderate)	1	2	1	3	2	2	4	1	1	2	3	1	1	0	0	0	24	(15)	15	(21)
Anterior displacement C2–3 (total)	5	3	4	4	4	4	4	1	2	3	3	1	1	0	0	0	39	(24)	28	(40)
Measured AP movement ≥3 mm	5	4	5	2	5	6	5	2	4	5	4	6	7	4	4	3	71	(44)	32	(46)
Number of children with measured AP movement >3 mm and observed anterior displacement at C2–3	4	3	3	1	3	4	3	0	1	3	1	1	1	0	0	0	28	(18)	21	(30)
Anterior displacement C3–4†	3	2	1	1	2	4	1	0	2	2	2	1	1	0	0	0	22	(14)	14	(20)
Overriding of anterior arch of atlas relative to odontoid (extension views)‡	2+	4++	3++	1	1+	3	0	1	0	0	0	0	0	0	0	0	14	(9)	14	(20)
Wide space between anterior arch of atlas and odontoid (flexion views)	2	2	3	2	2	2	1	0	0	0	0	0	0	0	0	0	14	(9)	14	(20)
																			Total (5–11 yr)	
																			No.	*(%)*
Presence of apical odontoid epiphysis	0	0	0	0	3	2	3	1	4	1	4	0	0	0	0	0	15	(9)	18	(26)
																			Total (1–5 yr)	
																			No.	*(%)*
Presence of basilar odontoid cartilage plate	10	9	9	6	4	0	0	0	0	0	0	0	0	0	0	0	48	(30)	38	(76)
Angulation at single level	1	4	1	1	3	3	2	0	1	2	1	2	2	1	2	0	25	(16)		
Absent lordosis in neutral position	3	0	0	0	0	0	0	1	2	1	3	2	2	5	1	2	22	(14)		
Absent flexion curvature C2–7 in flexion view	1	2	1	6	4	1	0	0	2	3	1	1	1	1	2	0	26	(16)		

*Boldface numbers represent predominant age range for particular variable.
†Twenty of 22 children with anterior displacement at C3–4 also had displacement at C2–3.
‡Presence of wide atlanto-odontoid space in same child (each + represents one child).
From Hensinger RN: Standards in Pediatric Orthopedics, p 42. New York, Raven Press, 1986. Originally from Cattell HS, Filtzer DL: Pseudosubluxation and other normal variations in the cervical spine in children: a study of one hundred and sixty children. J Bone Joint Surg 1965;47:1295.

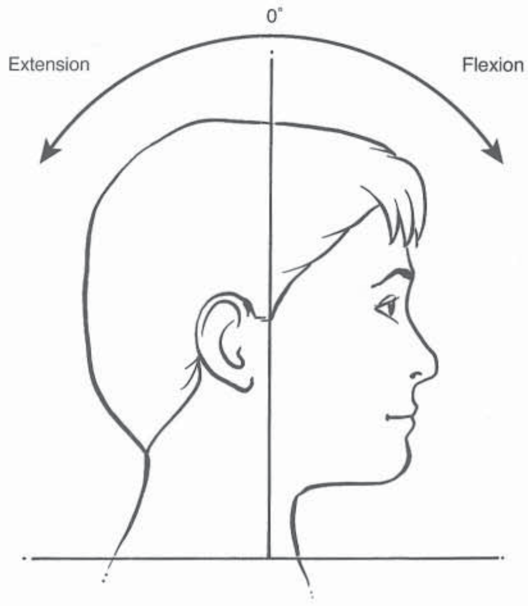


FIGURE 3–11 Assessment of flexion and extension of the cervical spine.

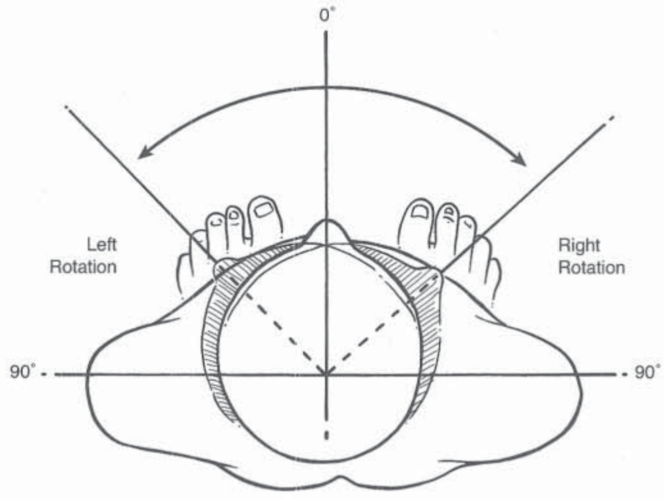


FIGURE 3–13 Measurement of rotation of the cervical spine.

play. Flexion can be measured in degrees or, if motion is limited, by the distance remaining between the chin and sternum on maximum forward bending. With normal range of flexion, the patient should be able to touch the chin to the chest, while with normal range of extension, the patient should be able to look at the ceiling.[36]

The zero starting position for measuring *lateral bending* and *rotation* is with the nose vertical and perpendicular to the axis of the shoulders (Fig. 3–12). Again, the trunk should be stabilized when testing lateral bending. The degree of bending is measured as the angle between the midaxis of the face and the beginning vertical line. Rotation is measured from the zero starting position (Fig. 3–13). If the neck is placed in maximum flexion, rotation is restricted to the upper cervical spine.[18] Normally, a child's cervical spine is mobile enough to permit touching of the ear to the adjacent shoulder when bending the neck, and touching of the chin to the shoulder when rotating the head.

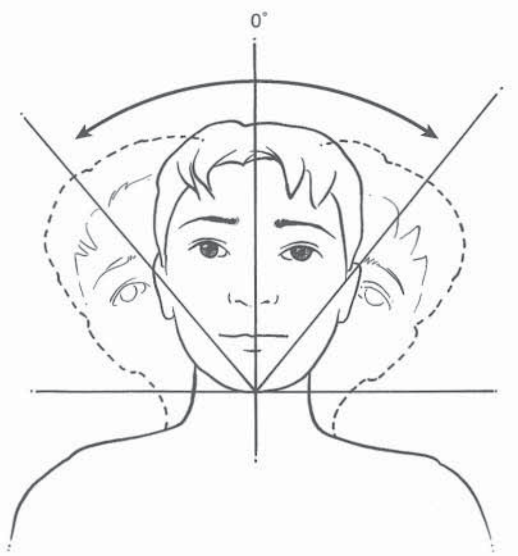


FIGURE 3–12 Assessment of lateral bending of the cervical spine.

Cervical spine disorders result in a decreased ROM in the affected vertebral segments.[19] However, because clinical demonstration of limited cervical motion indicates only that a disorder is present, radiographs are needed to determine the extent of the problem and its cause.

THE THORACOLUMBAR SPINE

Like motion of the cervical spine, thoracolumbar spine motion represents a combination of movements of several joints to produce flexion/extension, right and left lateral bending, and right and left rotation.[83,84] In the thoracic spine, flexion/extension is greatest in the lower thoracic spine, lateral bending is slightly increased in the lower thoracic region, and rotation is greatest in the upper thoracic segment. In the lumbar spine, flexion/extension is greatest in the lower lumbar vertebrae, lateral bending is most restricted at the lumbosacral junction, and rotational movements are relatively limited.

Accurately measuring thoracolumbar joint motion can be difficult. Assessment can be made by visual estimation, goniometric measurements, skin distraction, or inclinometer techniques.[30] The combination of extensive soft tissue coverage and obscured midline landmarks makes visual assessment extremely subjective and goniometric measurements difficult. The examiner usually is able to obtain more objective and accurate measurements of thoracolumbar motion using skin distraction[21,24,29,48,79] or inclinometer techniques.[42,65,71]

Skin distraction over the joints during flexion/extension and lateral bending can be measured with a tape measure, with the change in distance indicating the extent of motion.[29,85] However, this method does not provide the exact degrees of motion, cannot measure rotational movements, and is influenced by skin elasticity and the patient's size. On the other hand, the double inclinometer provides the ROM in degrees and can be used to measure motion in all planes. Moreover, measurements are not affected by skin elasticity or patient size.

Flexion. The zero starting position for measuring *flexion* is with the patient standing with the hips and knees straight, the trunk aligned with the lower limbs, the feet slightly apart, and the arms hanging to the sides in a relaxed, extended position (Fig. 3–14).[30] Measuring the distance between fingertips and floor when the patient is at maximum flexion (Fig. 3–15) is a simple technique, but this method of assessment has poor repeatability[85] and is not considered reliable for patients with low back problems. The *double inclinometer test* can be used to measure lumbar flexion more accurately, but the test requires two inclinometers and a cooperative patient (Fig. 3–16).[42,65,71] One inclinometer is placed over the sacrum and the other inclinometer is positioned over the spinous process of T12. With the patient in maximum flexion, the degree of flexion is obtained by subtracting the sacral inclinometer reading from the reading of the T12 inclinometer.

When examing the lower back, it is important to remember that limited flexion of the lumbar spine may be caused by disorders that do not involve the spine, such as any restriction of hip flexion or contractures of the hamstrings.

Extension. Back *extension* is evaluated by having the patient stand in the zero starting position with the palms on the buttocks and then bend backward as far as possible. Extension can be estimated visually or with a goniometer,[8,21,24] or it can be more accurately measured with the double inclinometer test (Fig. 3–17). One inclinometer is placed over the sacrum and the other inclinometer is positioned over T12. With the patient in maximum extension, the degree of extension is obtained by subtracting the sacral inclinometer reading from the reading of the T12 inclinometer.

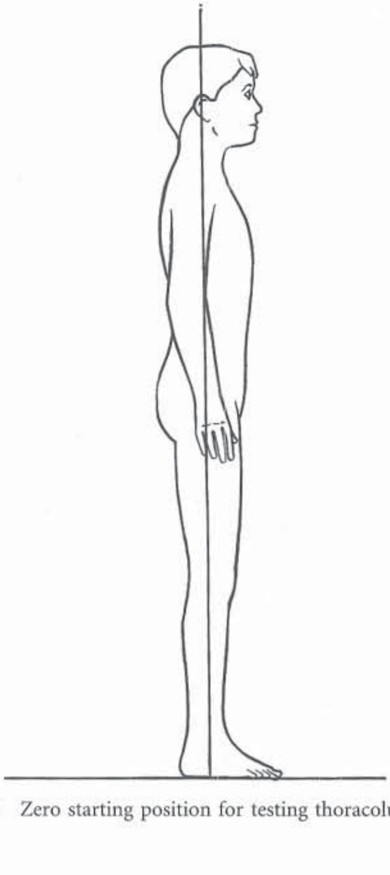


FIGURE 3–14 Zero starting position for testing thoracolumbar flexion.

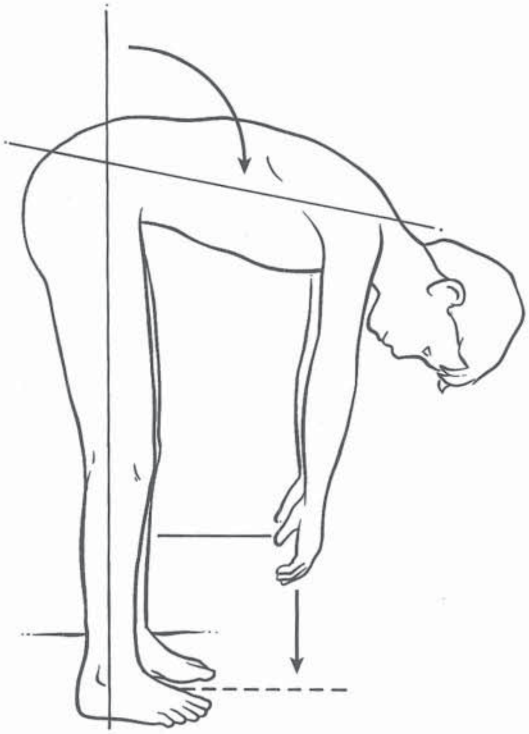


FIGURE 3–15 Visual inspection of thoracolumbar flexion. Normal lumbar lordosis disappears with flexion and a slight lumbar kyphosis is seen. When the patient is at maximum flexion, the examiner measures, the distance between the patient's fingertips and the floor.

Lateral Bending. Lateral *bending* is measured by marking the spinous processes of T1, T2, and S1, then having the patient start in the zero starting position and incline the trunk to the right and left while keeping the knees straight. The degree of bend can be estimated visually or with a goniometer.[21,24] Lateral bending also can be determined with a tape measure (Fig. 3–18).[53] The double inclinometer also can be used to measure lateral bending, with the inclinometers set the same as for measuring flexion and extension, and calculated by subtracting the sacral inclinometer reading from the T12 reading at maximum bending.

Rotation. Spinal *rotation* can be visually estimated by having the patient rotate to the right and left while the examiner holds the pelvis firmly in place and maintains the scapula in a neutral position. The degree of thoracolumbar rotation is estimated based on an imaginary line transecting the plane of the patient's shoulders (Fig. 3–19). Average spinal rotation is approximately 45 degrees.

THE HIP

The hip is a complex ball-and-socket joint capable of three-dimensional compound or rotatory motion. However, its ROM is significantly less than the shoulder's (also a ball-and-socket joint) because the acetabulum is substantially deeper than the glenoid. The normal range of hip motion for children at different ages has been published by a number of authors (Table 3–5).[15,25,30,31,77]

All normal newborns have some degree of flexion contracture of the hip and knee because of the intrauterine flexed posture (Fig. 3–20). Neonatal hip flexion contracture

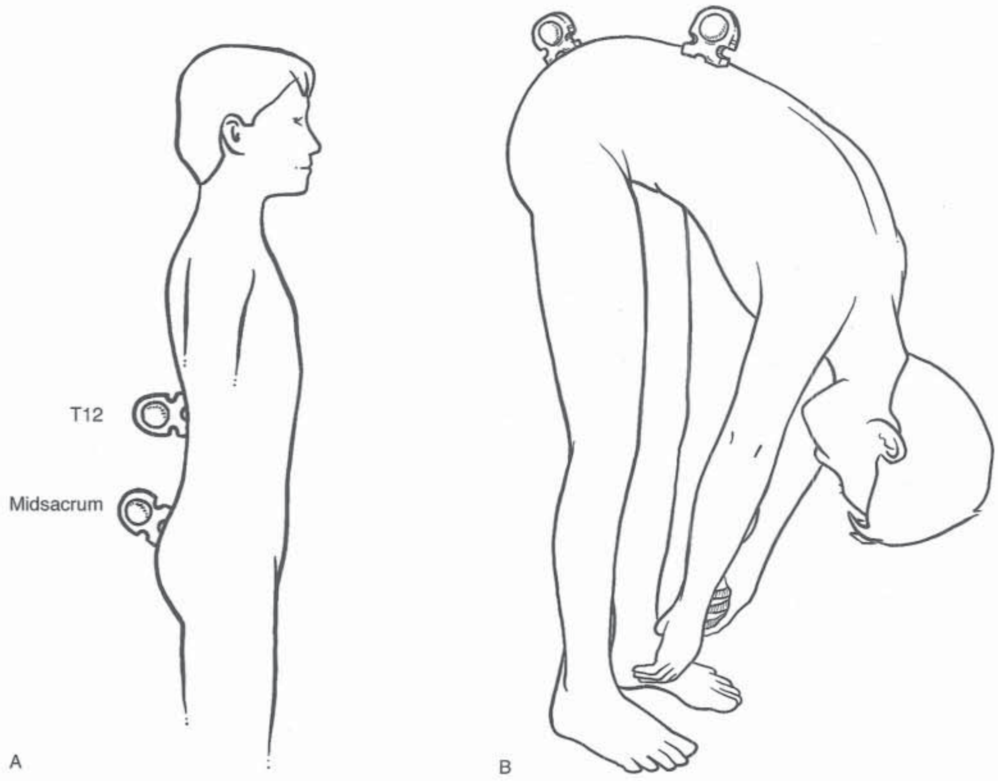


FIGURE 3–16 Double inclinometer test for lumbar flexion. **A,** One inclinometer is placed over the sacrum and the other is placed over T12. **B,** With the patient in maximum flexion, the degree of flexion is obtained by subtracting the sacral inclinometer reading from the reading of the T12 inclinometer.

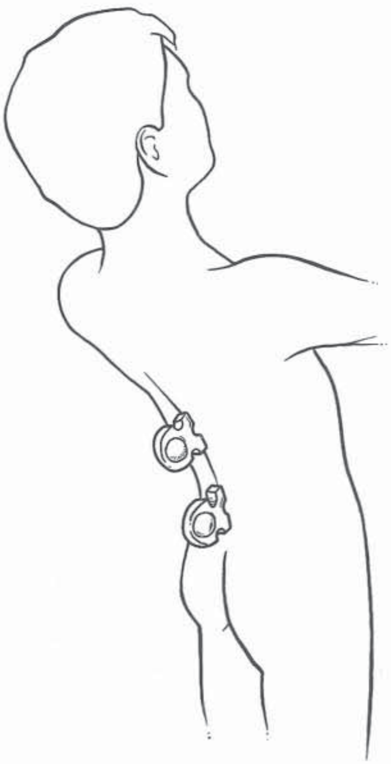


FIGURE 3–17 In the double inclinometer test for lumbar extension, one inclinometer is placed over the midsacrum and the other is placed over T12. With the patient in maximum extension, the degree of extension is obtained by subtracting the sacral inclinometer reading from the reading of the T12 inclinometer.

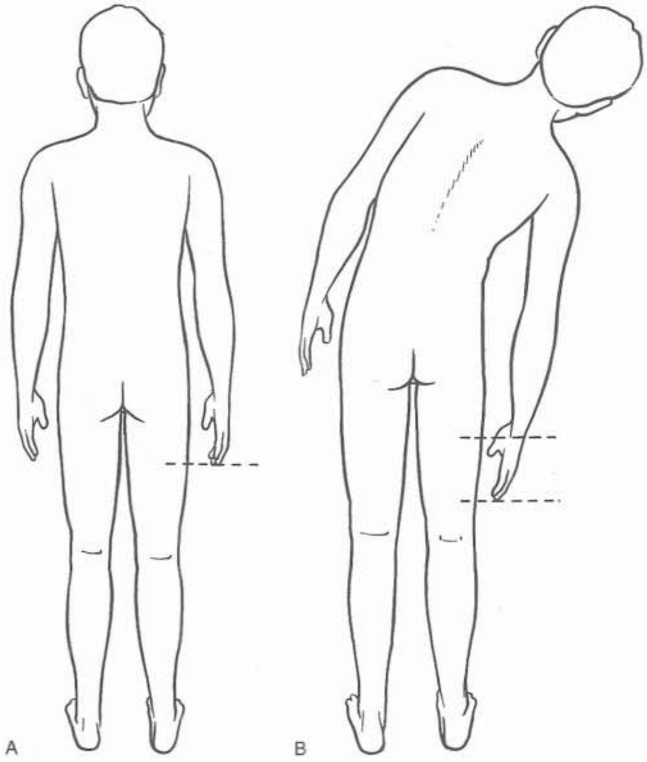


FIGURE 3–18 Measuring lateral bending of the thoracolumbar spine. **A,** The patient stands in the zero starting position, with the arms hanging down by the sides. **B,** When the patient is in maximum lateral bend, the fingers usually touch the knee.

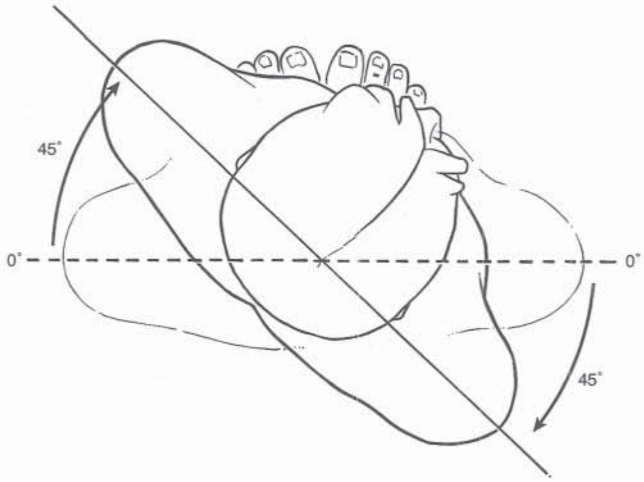


FIGURE 3–19 Visual estimate of thoracolumbar rotation. The patient rotates to the right and left while the examiner holds the pelvis firmly in place and maintains the scapula in a neutral position. The degree of rotation is estimated based on an imaginary line transecting the plane of the shoulders.

is typically about 30 degrees, but various studies have reported ranges from 20 to 60 degrees.[25,31,35,74,82] The neonatal hip also has more external rotation than internal rotation.[25,31] By 4 to 6 months of age, the hip and knee usually can be extended to neutral positions, and by 1 year of age, the hip flexion contracture and excessive external rotation have gradually resolved.[15,64]

Newborns also have greater range of hip rotation (average, 170 degrees[25]) than children 1 year old or older (average, 90 to 100 degrees). This increase in hip rotation may be due to the associated flexion contracture, insofar as rotation is greater when the hip is flexed. With increasing age, hip rotation decreases by 15 to 20 degrees each decade during the first 20 years, and by about 5 degrees per decade thereafter. Hip abduction decreases on average by 10 to 15 degrees per decade for the first 20 years.

Flexion/Extension. It is important to carefully observe the pelvis while examining passive motion of the hip joint. Significant flexion deformity may be hidden by forward tilt of the pelvis and excessive lumbar lordosis. During examination of hip motion, the examiner should ensure that the pelvis does not rotate or tilt. The examiner should place one hand on the iliac crest or anterior superior iliac spine to note the point at which the pelvis begins to move. The examination starts with the patient lying supine on a flat, firm surface. First one hip and then the other is held in full flexion. Normal range of hip flexion is from zero to 110 or 120 degrees (Fig. 3–21).

Hip extension (or lack of full extension [flexion contracture]) is tested with the patient in the supine position using the *Thomas test* (Fig. 3–22). Both of the patient's hips are completely flexed until the lumbar spine (which serves as a reference point) is flattened. The hip to be tested is then extended while the opposite hip remains flexed until the pelvis rotates. At the point where further extension is not possible, the angle between the thigh and the examining table is the degree of flexion deformity.

TABLE 3–5 **Normal Range of Hip Motion in Children at Different Ages (in Degrees)**

Motion	Newborn	4 Years	8 Years	11 Years
Flexion	128 ± 4.8	150 ± 12.5	146 ± 11.3	138 ± 14.5
Extension	−30 ± 3.9	29 ± 6.3	27 ± 6.3	25 ± 14.0
Abduction	79 ± 4.3*	54 ± 9.0	49 ± 7.3	45 ± 10.8
Adduction	17 ± 3.5	30 ± 5.0	28 ± 6.0	29 ± 6.3
Internal rotation	76 ± 5.6	55 ± 17.8	54 ± 17.5	48 ± 16.0
External rotation	92 ± 3.0	46 ± 16.8	43 ± 17.5	f42 ± 15.3

Note: Data are means ± 1 SD for newborns and ± 2 SD for other age groups.
*Measured in flexion. Measurements at other ages in abduction with hip extended (in neutral).
From Greene WB, Heckman JD: The Clinical Measurement of Joint Motion. Rosemont, IL, American Academy of Orthopaedic Surgeons, 1994.

FIGURE 3–20 Typical position of the neonate with vertex presentation. The hips and knees are flexed, the lower legs are rotated internally, and the feet are rotated further inward on the lower leg. The lower limbs are contracted into this position for a variable period following birth.

FIGURE 3–21 Normal range of hip flexion.

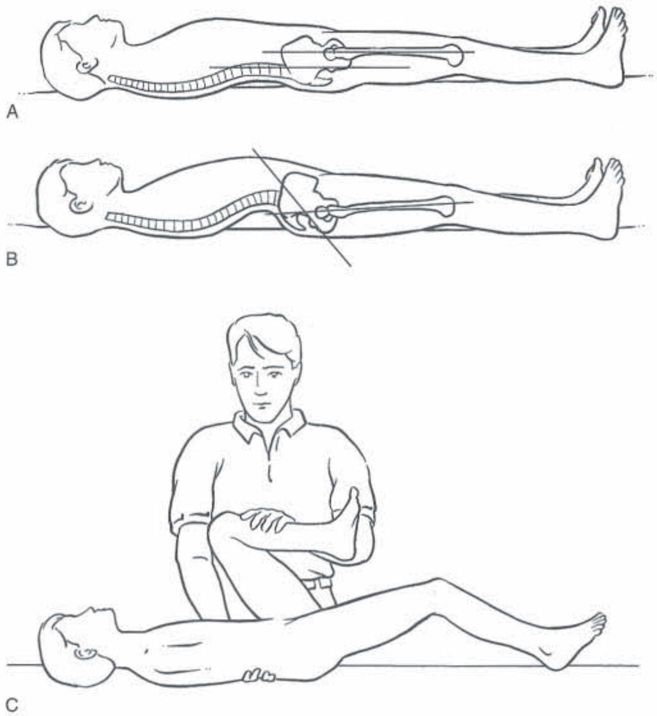


FIGURE 3–22 The Thomas test. **A,** In the supine position, normal lumbar lordosis will be present in fully extended hips. **B,** If flexion contracture is present, the legs will still lie on the examining surface, but there will be increased lumbar lordosis. **C,** The Thomas test is performed by first flexing *both* hips until the lumbar spine is flattened, then extending the affected hip. The amount of flexion contracture is represented by the angle between the thigh and the examining surface.

Hip flexion deformity can also be determined by having the patient lie prone with both hips flexed over the end of the table to flatten the lumbar spine (Fig. 3–23).[75] The pelvis is stabilized by the examiner's placing a forearm over the ilium and lumbosacral spine. Then, with the opposite hand, the examiner raises the patient's thigh toward the ceiling and extends the tested hip (motion of the lower spine should be prevented during this maneuver). Normally, a hip should extend 10 to 20 degrees. If the joint cannot be brought to neutral position, there is flexion deformity. The degree by which the hip fails to reach neutral position is the degree of deformity (Fig. 3–24). If flexion deformity of the hip is significant in the standing position or if the patient is unable to compensate exclusively by increased lumbar lordosis, the knee of the affected limb will be held in flexion and only the toes will touch the ground. This causes the extremity to look shorter than the opposite limb.

Abduction/Adduction. When evaluating hip *abduction,* it is important that the anterior superior iliac spines be level. Abduction can be assessed with the patient's legs straight or with the patient's knees and hips in 90 degrees of flexion (Fig. 3–25). The latter position is commonly used when examining newborns and young infants. With the patient still supine, the pelvis is held in a fixed position by abducting the opposite hip, and steadied by the examiner's hand, which will detect any pelvic motion (Fig. 3–26). Abduction is measured in degrees of outward motion of the limb from the zero starting position. The normal amount of hip abduction with the hip in extension is 30 to 45 degrees.

Hip abduction can also be rapidly and grossly assessed by having the patient spread the legs as far apart as possible while standing or lying supine. The degree of abduction is determined by measuring the intramalleolar separation or the angle made by the legs when abduction is symmetric.

FIGURE 3–23 The amount of hip flexion deformity can also be determined with the patient prone. The pelvis is stabilized, the patient's thigh is raised toward the ceiling, and the tested hip is extended. Normal extension is 30 degrees.

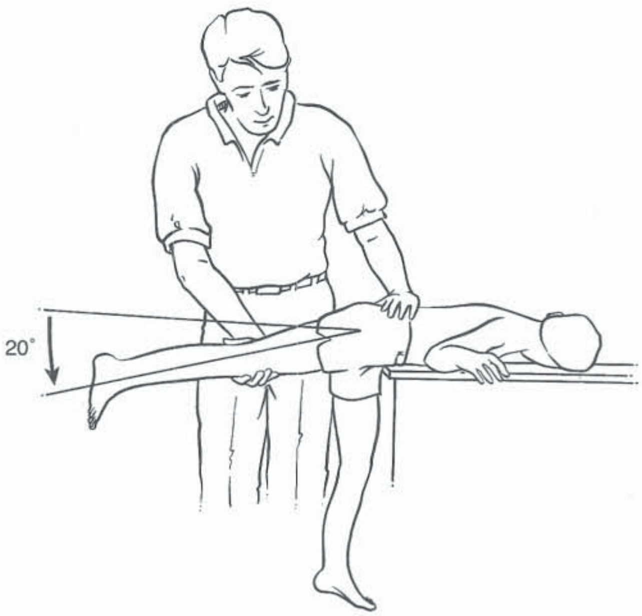


FIGURE 3–24 The degree by which the hip fails to reach neutral position is the degree of deformity.

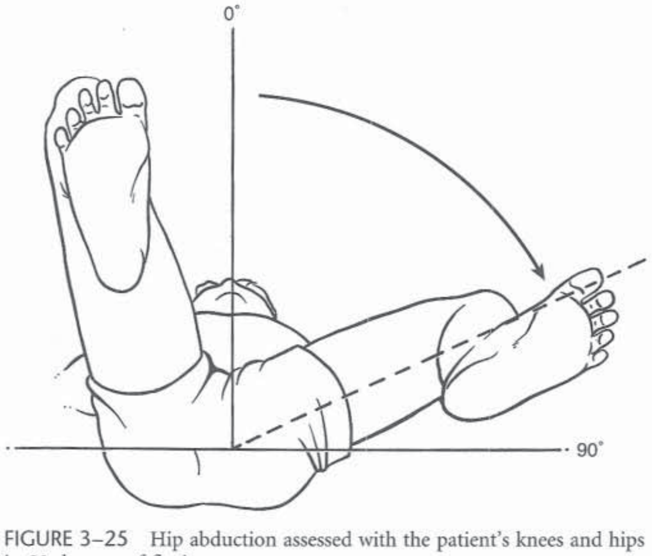


FIGURE 3–25 Hip abduction assessed with the patient's knees and hips in 90 degrees of flexion.

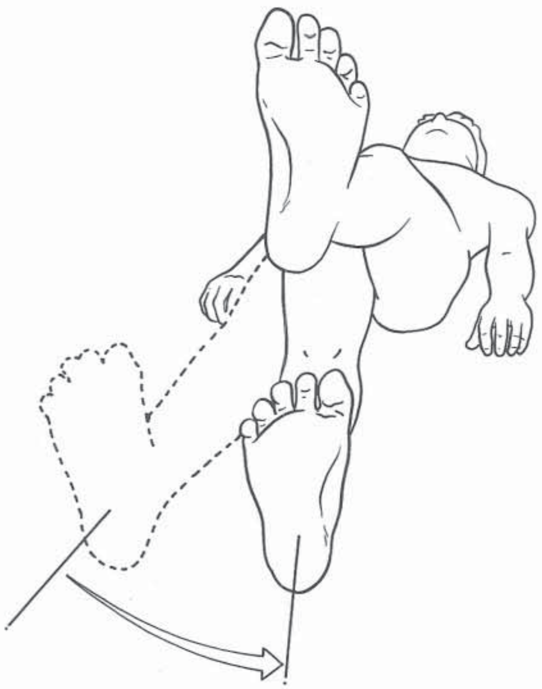


FIGURE 3–27 Adduction of the hip. The opposite limb is raised so that the tested leg can pass under it.

When assessing *adduction* of the hip, the examiner should raise the opposite limb so that the tested leg can pass under it (Fig. 3–27). Adduction can also be assessed by passing the examined leg over the opposite leg, but the estimation of the amount of adduction will be slightly inaccurate because the hip will be flexed.

The presence and degree of abduction contracture of the hip is determined by *Ober's test* (Fig. 3–28).[59] With the patient lying on the side opposite the one being tested, the underneath hip and knee are maximally flexed to flatten the lumbar spine and stabilize the pelvis. The hip to be tested is then flexed to 90 degrees (with the knee flexed to a right angle), fully abducted, and brought into full hyperextension and allowed to adduct maximally. During this maneuver, the knee of the tested extremity should always be kept at 90 degrees of flexion. The angle of the thigh and a horizontal line parallel to the examination table represents the degree of abduction contracture. A normal limb will drop well below this horizontal line. If there is abduction contracture, the hip cannot be adducted to neutral position.

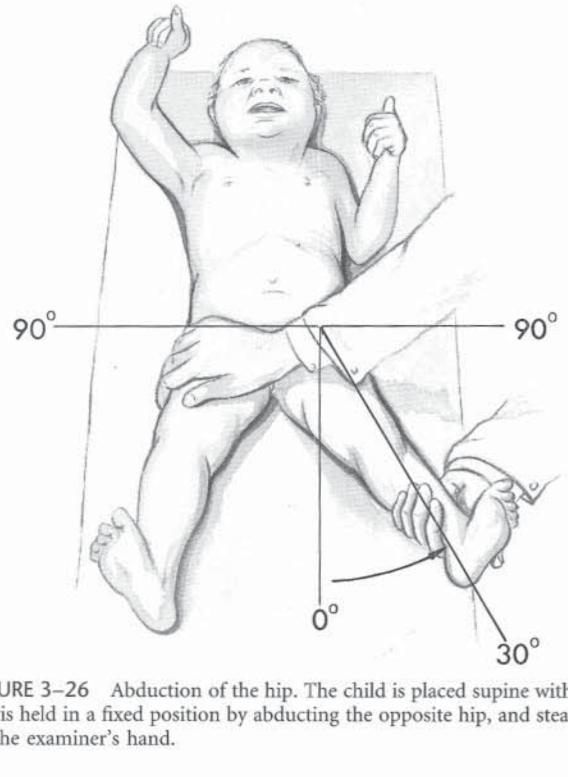


FIGURE 3–26 Abduction of the hip. The child is placed supine with the pelvis held in a fixed position by abducting the opposite hip, and steadied by the examiner's hand.

When examining infants for evidence of hip abduction contracture, the examiner should place them prone and stabilize their pelvis in a neutral position with the legs abducted, then gently adduct one leg at a time. With an abduction contracture, the pelvis will move under the examiner's hand as the leg is adducted.

Rotation. Rotation of the hip in *flexion* is assessed with the patient supine and the hip and knee of the limb to be examined both flexed 90 degrees (Fig. 3–29). *Internal (inward) rotation* of the hip is measured by rotating the lower leg externally away from the midline of the body, with the thigh as the axis of rotation. *External (outward) rotation* of the hip is measured by rotating the lower leg internally toward the midline of the body, again with the thigh as the axis of rotation.

Rotation of the hip in *extension* is best assessed with the patient prone and the knee flexed 90 degrees (Fig. 3–30). During the maneuver, the pelvis should be stabilized to ensure that the rotation is entirely femoral. *Internal rotation* of the hip is measured by rotating the leg outward, *external rotation* is measured by rotating the leg inward. The tibiae are used as markers to facilitate measurement as the hips

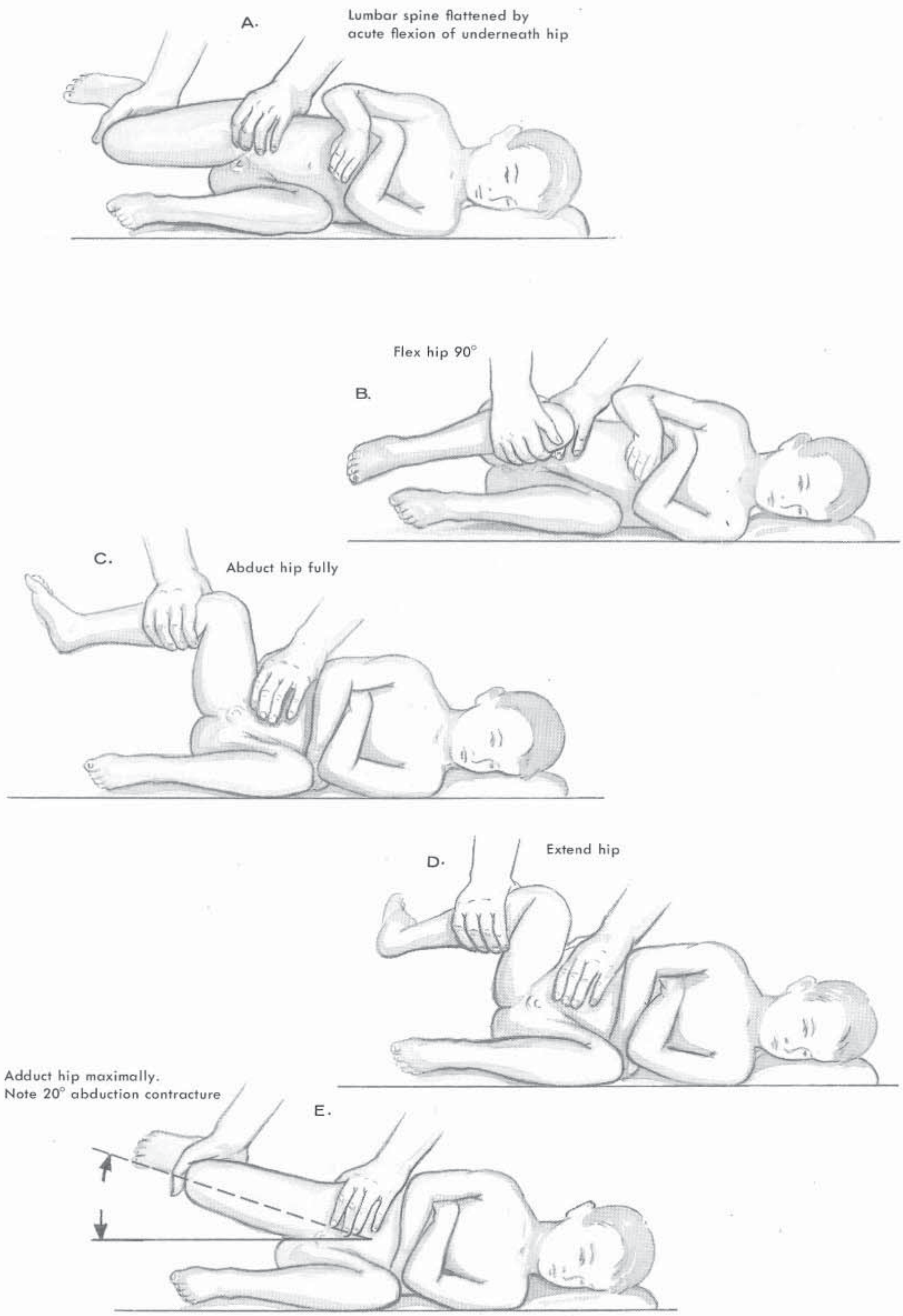


FIGURE 3–28 Ober's test for determining the presence and degree of abduction contracture of the hip.

are rotated internally and externally. The normal amount of internal and external rotation in extension is 45 degrees at skeletal maturity. Younger patients typically have more total rotation, and more internal than external rotation (see Table 3–5).

Trendelenburg's Test. Examination of the hip in ambulatory patients must include an assessment of the presence or absence of *Trendelenburg's sign* by performing *Trendelenburg's test.* During the test, the examiner is seated behind the patient and the patient is sufficiently undraped that the

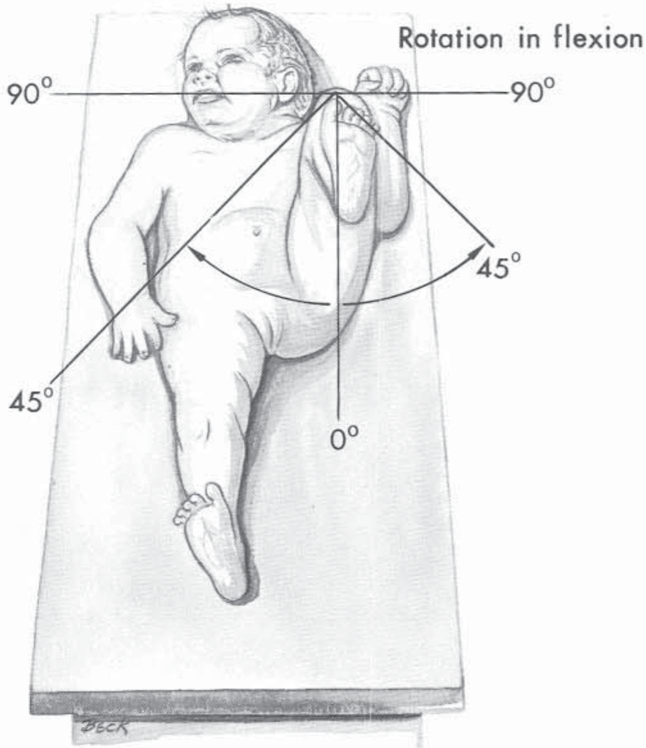


FIGURE 3–29 Rotation of the hip in flexion is assessed with the patient supine and the hip and knee flexed 90 degrees.

examiner can see the pelvic area, including the iliac crests and the lower extremities. The test is performed by having the patient first stand evenly on both legs and then stand on one leg, holding the opposite leg up by flexing the hip and knee. The examiner rests his or her fingers on the iliac crests or the fingertips over the skin dimples overlying the posterior iliac spines.

During a normal examination, the patient will elevate the unsupported pelvis by abducting the stance-leg hip, using the hip abductor musculature (primarily the gluteus medius) to bring the center of gravity over the stance leg. To conduct the examination properly, the patient should not be allowed to support him- or herself by holding on to a table, wall, or other surface (unless ataxia prevents the patient from otherwise performing the test). Nor should the patient be allowed to brace the unsupported leg against the stance leg. Absence of Trendelenburg's sign (i.e., a normal examination) indicates that the patient has adequate hip joint range and arc of motion, normal morphology, no inflammation in or around the joint, good to normal muscle strength, and normal central and peripheral neurologic functions.

Any deviation from the above will result in a positive test, or will make it difficult for the examiner to properly assess the presence or absence of Trendelenburg's sign. Trendelenburg's sign is present (i.e., the test is positive) if the unsupported side drops when the patient attempts to stand on one leg, usually with exaggeration of lateral flexion of the lumbar spine in an attempt to place as much body mass as possible over the stance leg (Fig. 3–31).

There are a number of variations of Trendelenburg's test. The "delayed" Trendelenburg sign is assessed by having the patient stand unsupported for a prescribed period of time (such as 10 seconds). An alternative is the stress Trendelenburg test: as the patient stands on one leg, the examiner pushes down on the shoulder on the unsupported side to manually test the abductor strength of the opposite (supporting) hip (Fig. 3–32).

The presence or absence of Trendelenburg's sign in a patient in the standing position is different from the behavior of the hips, pelvis, and hip abductor muscles during normal gait. During normal gait, the pelvis on the unsupported side lowers owing to adduction of the stance hip controlled by the eccentric contraction of the stance limb (see Chapter 5, Gait Analysis).

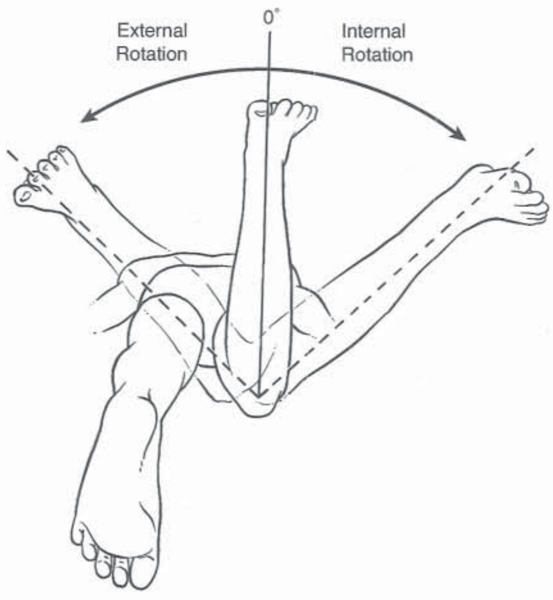


FIGURE 3–30 Rotation of the hip in extension is assessed with the patient prone and the knee flexed 90 degrees.

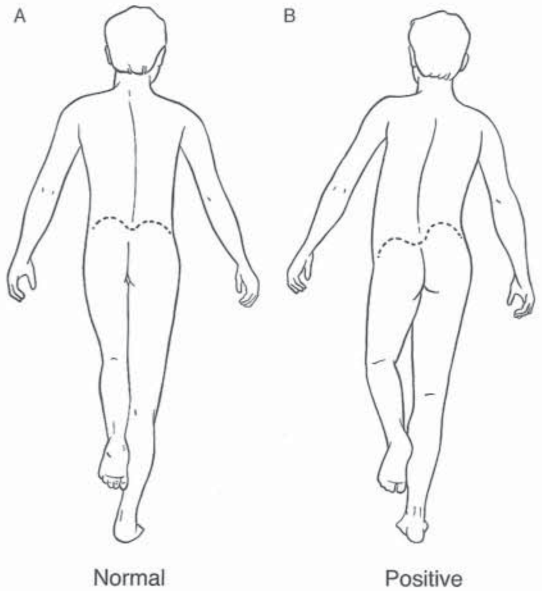


FIGURE 3–31 Trendelenburg test. **A,** Normal; Trendelenburg's sign is not elicited. **B,** Positive test; Trendelenburg's sign is elicited.

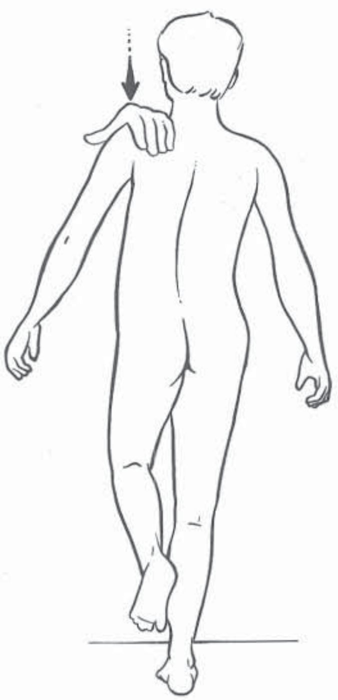


FIGURE 3–32 The "stress" Trendelenburg test. The patient is positioned the same as for the traditional Trendelenburg test. The examiner then pushes on the shoulder on the unsupported side to test the strength of hip abductors on the supporting side.

THE KNEE

The primary knee motions measured are *flexion* and *extension*. Although rotation of the tibia on the femur occurs during knee movement, it cannot be accurately measured by physical examination alone.[30] The zero starting position for assessing knee flexion is with the patient sitting or supine and the leg fully extended (Fig. 3–33). The degree of flexion is how far the knee can be bent from zero degrees to its maximum flexion. Extension is measured in degrees opposite to flexion at the zero starting position. In the normal knee, flexion is restricted only by the calf abutting the thigh, and extension should be to zero degrees. A few degrees of knee hyperextension may be seen in young children,[13,86] but this usually decreases with age.

THE ANKLE AND FOOT

The primary motions of the ankle (tibiotalar joint) are *flexion* (i.e., dorsiflexion) and *extension* (i.e., plantar flexion). The zero starting position for measuring ankle motion is with the knee flexed (to relax the gastrocnemius muscle) and the foot perpendicular (at a right angle) to the tibia (Fig. 3–34). The goniometer is aligned with the axis of the foot by placing it along the lateral border of the foot.

Dorsiflexion is measured by having the patient move the foot toward the anterior surface of the leg, while plantar flexion is measured when the foot is moved away from the anterior surface of the leg.[22] During dorsiflexion and plantar flexion, most of the motion takes place at the tibiotalar joint, but other joints are also involved.[46,60,73]

In the foot, consistency in choosing landmarks is important to ensure accurate reproducibility. Active ROM measurements appear to provide more consistent measurements than passive ROM assessment and should be used whenever possible.[30] With infants and young children, active ROM assessment may not be reliable and passive ROM evaluation may be necessary to assess joint motion.

Because there are many joints in the foot, it is difficult to accurately measure the motion of a specific joint complex. In children, the degree of joint motion is normally the same in the right and left foot. Thus, it is possible to compare the affected foot with the opposite foot to determine any limitation of motion.[9]

Foot motion occurs in the planes of inversion/eversion and supination/pronation. *Inversion* and *eversion,* which are tested passively, primarily demonstrate motion at the talocalcaneal joint. The motions are estimated in degrees, or

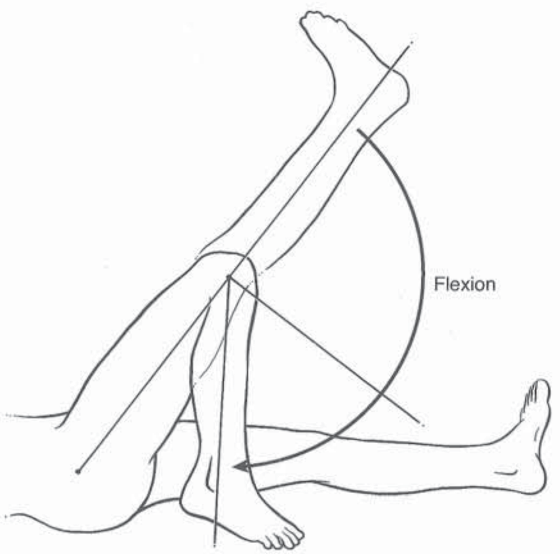


FIGURE 3–33 Assessment of knee range of motion.

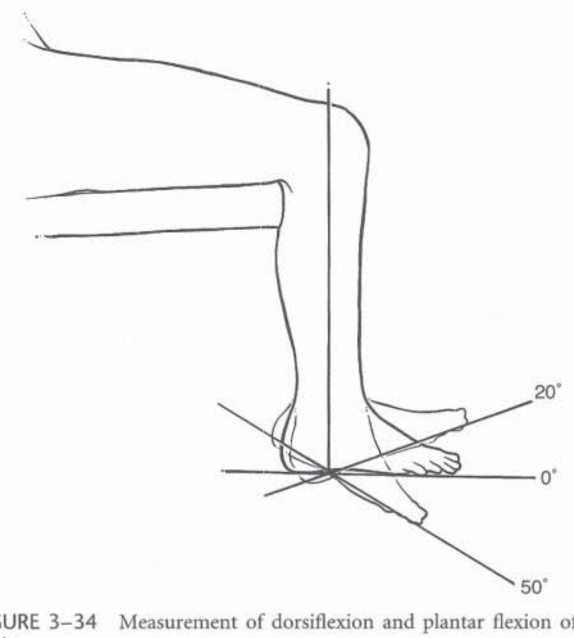


FIGURE 3–34 Measurement of dorsiflexion and plantar flexion of the ankle.

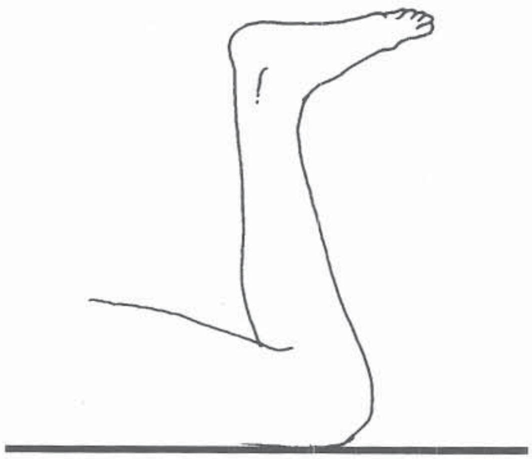


FIGURE 3–35 Zero starting position for testing foot motion. The patient is prone, the knee is flexed, and the ankle is in gentle dorsiflexion. (Reproduced from Greene WB, Heckman JD: The Clinical Measurement of Joint Motion. Rosemont, IL, American Academy of Orthopaedic Surgeons, 1994.)

percentages of motion compared with the opposite foot. The zero starting position is with the patient prone, the knee flexed, and the ankle in gentle dorsiflexion (Fig. 3–35).[30,51] Flexion of the knee to 130 degrees places the axis of the heel (subtalar joint) closer to the horizontal plane,[50,51] and having the foot in dorsiflexion (i.e., just before the soft tissues become tight) restricts lateral motion of the tibiotalar joint and better denotes subtalar joint motion.[30] Inversion is assessed by stabilizing the ankle with one hand, firmly grasping the hind part of the foot in the cup of the hand, and turning the heel inward with the ankle in a zero neutral starting position (Fig. 3–36A). Eversion is assessed by turning the heel outward (Fig. 3–36B). The degrees of motion are recorded with a goniometer.

Supination and *pronation,* which are tested actively, are more complex motions that involve all the joints of the

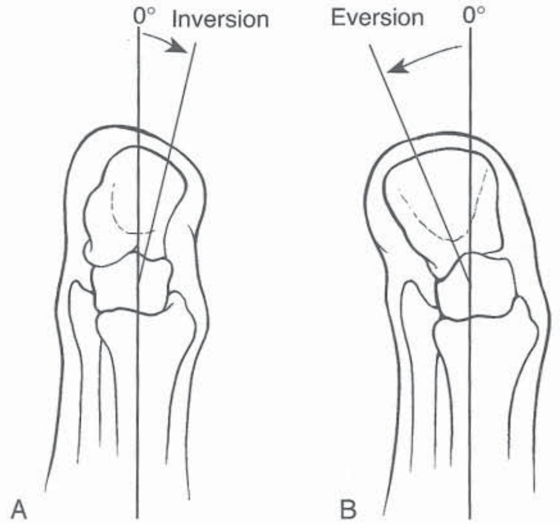


FIGURE 3–36 Assessment of (A) inversion and (B) eversion of the ankle. (Reproduced from Greene WB, Heckman JD: The Clinical Measurement of Joint Motion. Rosemont, IL, American Academy of Orthopaedic Surgeons, 1994.)

foot.[47] Active supination (which entails inversion, adduction, and plantar flexion of the midfoot) is assessed by having the patient direct the forepart of the foot so that the sole is turned medially (Fig. 3–37A). Pronation (which is made up of eversion, abduction, and dorsiflexion of the midfoot) is assessed by having the patient turn the foot so that the sole is turned laterally (Fig. 3–37B).

Muscle Strength

The evaluation of muscle strength is often an important part of the orthopaedic physical examination. Detailed descriptions of the techniques for testing specific muscles are available in a number of textbooks.[16,36,43] In general, during the orthopaedic physical examination, proximal muscles are tested as functional groups (e.g., hip abductors, hamstrings) and distal muscles are tested separately (e.g., flexor pollicis longus, extensor digitorum communis).

The examiner should look for a pattern in any detectable weakness. Specific patterns may indicate a lower motor neuron lesion affecting a peripheral nerve or nerve root. Weakness that worsens with repeated effort and improves with rest suggests myasthenia gravis. Repetitive testing also may reveal lack of endurance, which is a more subtle form of weakness.

Examining infants and young children for muscle weakness can be difficult. Gross defects in movements can be detected by observing the spontaneous activity of the infant and watching the small child at play. The examiner should also watch the child walk, run, climb stairs, or get up from the floor. Stimulating reflexes such as the Moro reflex can also be a means of determining muscle strength in infants.[40,88] For older patients, the strength of various muscle groups (e.g., hip flexors, hamstrings, quadriceps) can be quantified by using dedicated muscle power testing machines such as the Cybex, or similar devices.

Muscle strength and power can be classified as *kinetic* or *static.* Kinetic power is the force employed when changing positions and is tested by having the patient perform movements against gravity or against resistance provided by the examiner. Static power is the force employed when resisting movement and is tested by having the patient resist active effort by the examiner to move specific parts of the patient's body. *Paresis* or *weakness* denotes an impairment of muscle strength, while *paralysis* means complete loss of strength. In addition to a loss of kinetic and static power, patients with muscle weakness will exhibit increased fatigue, decreased rate of motion, irregular and clumsy movements, tremors, lack of coordination, and diminished ability to perform skilled acts.

If a patient has muscle weakness, the examiner needs to determine whether it is *localized* or *diffuse.* Localized (or focal) loss of muscle strength may be due to involvement of a specific *muscle,* of a *nerve* that innervates various muscles, or of a certain *segment of the spinal cord* that innervates a group of muscles. Localized muscle weakness may also involve multiple muscles that affect a specific *movement* or an *entire limb. Monoplegia* refers to paralysis of one limb, *hemiplegia* to paralysis of one-half of the body, *diplegia* to relatively symmetric involvement of the right and left sides with greater involvement of the legs than the arms (double

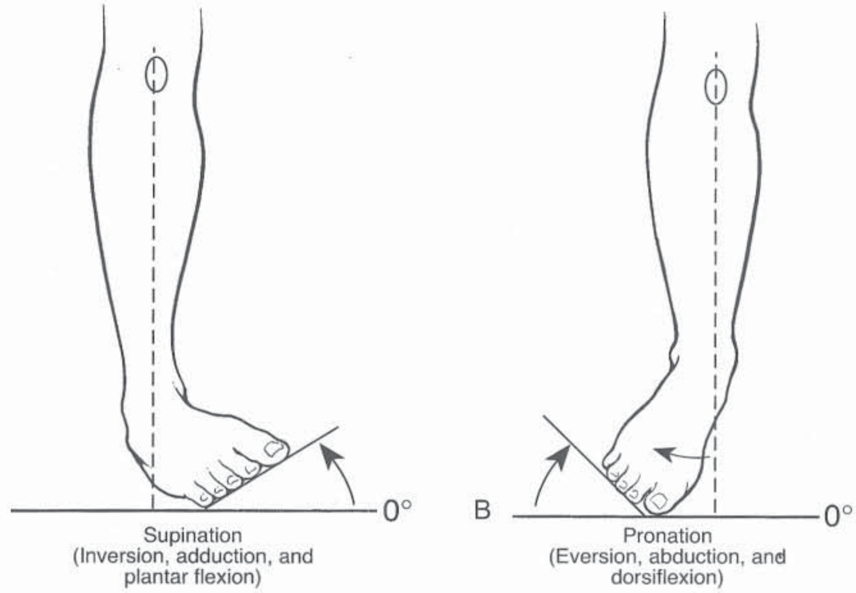


FIGURE 3–37 Assessment of (A) supination and (B) pronation of the ankle. (Reproduced from Greene WB, Heckman JD: The Clinical Measurement of Joint Motion. Rosemont, IL, American Academy of Orthopaedic Surgeons, 1994.)

hemiplegia), *paraplegia* to paralysis of the lower limbs, and *quadriplegia* or *tetraplegia* to paralysis of all four limbs. Weakness of one side of the body suggests an upper motor neuron lesion. A polyneuropathy causes symmetric distal weakness, and a myopathy usually causes proximal weakness. Diffuse (or generalized) loss of muscle strength may be due to myopathies (such as the muscular dystrophies), various types of myositis and myasthenia gravis, electrolyte imbalance, and toxic and deficiency states.

The extent, nature, and cause of the muscle weakness must also be determined. The examiner should ascertain whether there are associated sensory changes, whether the reflexes have been affected, whether muscle atrophy is present, whether there is muscle fibrillation or fasciculation, and whether paralysis (if present) is flaccid or spastic. If a muscle is kept in a shortened, contracted position for an extended period of time, a *myostatic contracture* may develop that prevents the muscle from being stretched back to its original length. Myostatic contractures may result from overaction of one group of muscles unopposed by weakened antagonists or from prolonged muscle spasms, as occur in acute poliomyelitis or in association with spastic paralysis. Contractures and bone and joint deformities may increase muscle weakness. If there is limitation or absence of range of motion of a joint, the examiner should determine if it is the result of swelling of the joint, fibrous or bony ankylosis, voluntary or involuntary muscle spasm, or paralysis. Finally, the orthopaedist must decide if the muscle weakness is a permanent condition or a reversible process, and if surgical intervention can improve function.

The examiner should objectively grade and record the degree of muscle strength on a chart so that the patient's progress can be followed by comparative tests. A sample of the comprehensive muscle test record for the upper and lower extremities as used at Texas Scottish Rite Hospital for Children is reproduced in Appendix 3–2.

The original method of testing and grading muscle strength published by Lovett and Martin[44,45] is still helpful in evaluating a patient's neuromuscular status (Table 3–6). Another system that is commonly used for grading muscle strength is based on a scale of 0 to 5 (Table 3–7). At Texas Scottish Rite Hospital for Children, we have modified these

TABLE 3–6 **Lovett and Martin's Grading of Muscle Strength**

Grade	Description
Zero	No palpable contraction of muscle
Trace	Palpable contraction of muscle; no motion of part that muscle should move; no joint motion when gravity is eliminated
Poor	Muscle able to move part through its complete ROM when gravity is eliminated, but not against gravity
Fair	Muscle able to carry part through its complete ROM against gravity, but not against added resistance
Good	Muscle able to carry part through its complete ROM against gravity with some resistance ("good minus" and "good plus" used to indicate variations in resistance)
Normal	Muscle exhibits normal strength; is able to carry part through its complete ROM with full resistance
Modified Grades Used in Practice	
Poor minus	Muscle able to move part, but not through complete ROM and not against gravity
Fair minus	Muscle able to move part against gravity, but not through complete ROM

TABLE 3–7 **Grading of Muscle Strength**

Grade	Description
0	No muscular contraction detected
1	Trace of contraction barely detectable
2	Active movement with gravity eliminated
3	Active movement against gravity
4	Active movement against gravity and some resistance
5	Active movement against full resistance

grading systems to record results on the manual muscle evaluation test. Grades of muscle strength range from 0 to 5, with grades 1 through 4 further defined as poor minus, poor plus, fair minus, fair plus, good minus, and good plus (Table 3–8).

Innervation of the muscles responsible for movements of the shoulder and upper limb is given in Table 3–9, and innervation of the muscles responsible for movements of the lower limbs is given in Table 3–10.

Neurologic Assessment

A detailed neurologic examination is important in the diagnosis of musculoskeletal disorders. This is particularly true when there is evidence of muscle weakness, incoordination, or other disturbances in neuromuscular function. The examiner should assess the patient's developmental reflexes, deep and superficial reflexes, sensory function, cranial nerves, and mental and emotional state.

DEVELOPMENTAL REFLEXES

A number of primitive reflexes (infantile automatisms) are present in neonates and infants and are associated with normal development. Primitive reflexes are present at birth and disappear as the child matures. Other reflexes appear during infancy and young childhood, and some continue throughout life.

The two major divisions of the CNS that control neuromuscular functions are the cerebral cortex and the subcortical nuclei. At birth, the behavior patterns characteristic of the neonate are mediated by the subcortical nuclei, with some functions essentially remaining under its control throughout life. As the cerebral cortex develops, it exercises greater influence over neuromuscular functions and also an inhibitory influence on some of the activities of the subcortical nuclei. Cortical maturation is reflected in behavior by the suppression or diminution of certain neuromuscular activities, and by the emergence and integration of other neuromuscular performances. Development tends to proceed in a cephalocaudal direction.[52]

The reflexes and reactions discussed in this section are the most important ones, and the orthopaedist should be most familiar with them, because there is an association between functional motor achievement and the underlying reflex structure. The absence or presence of these reflexes may be a negative or positive predictor of immediate or eventual cortical function. Their absence often indicates a delay in normal neurologic development, and their persistence beyond the expected time of disappearance suggests neurologic impairment or dysfunction.[28] The normal timing of the appearance and disappearance of these reflexes and reactions is summarized Table 3–11 and illustrated in Figure 3–38.

TABLE 3–8 **Grading of Muscle Strength (Texas Scottish Rite Hospital for Children)**

Grade	Description
0	Absent
1T	Trace, mere tension on palpation
1P−	Poor minus, beginning motion
2P	Poor, full range, gravity-eliminated
2P+	Poor plus, begin motion antigravity
2F−	Fair minus, almost full range antigravity
3F	Fair, full range antigravity
3F+	Fair plus, full range, minimal resistance
3G−	Good minus
4G	Good, full range, moderate resistance
4G+	Good plus
5	Normal, maximum resistance

Palmar (Hand) Grasp Reflex. The hand grasp reflex is tested with the infant supine, the arms semiflexed, and the head in the midline position (not rotated to one side or the other). If the head is not in the midline, the grasp reflex will be more pronounced on the side to which the occiput is directed. It is also important not to touch the dorsum of the infant's hand during the test. Such tactile stimulation will cause the infant to open the hand instinctively, resulting in a conflict between reflexes.

To elicit the hand grasp reflex, the examiner places a finger or an object (e.g., a pencil, rod, an empty thermometer case) into the infant's palm from the ulnar side. This will stimulate the palm and enhance flexor tonus, and the fingers will flex and grip the object (Fig. 3–39). The thumb will not oppose the fingers but will flex with them if it was in an extended position before the object was introduced. If the object is retracted after the infant grasps it, the flexor tone is increased synergistically in other flexor muscles of the upper limb and is facilitated by stretch. This causes the muscles of the arm and shoulder girdle to contract. If the response is marked, the grip will be so strong that it will be possible to suspend the infant for a moment by the object being held.

The hand grasp reflex is present in neonates and very young infants and normally disappears between 2 and 4 months of age. The hand grasp reflex is strongest at birth. The examiner should assess its intensity and symmetry. The reflex may be asymmetric in patients with spastic hemiplegia. Absence on one side may indicate flaccid paralysis, such as that seen in obstetric brachial plexus paralysis. The reflex should also be assessed for persistence after it should have normally disappeared. Persistence in infants older than 4 months may be an indication of flexor hypertonicity, as is seen in spastic cerebral palsy.

Plantar (Foot) Grasp Reflex. The plantar grasp reflex in the foot is very similar to the hand grasp reflex.[27] The reflex is tested with the infant supine. When light digital pressure is applied to the plantar surface of the foot (especially on its distal portion just proximal to the toes), tonic flexion and adduction of the toes should occur (Fig. 3–40).

The plantar grasp reflex is present in neonates and infants and usually disappears between 9 and 12 months of age. Its absence may indicate flaccid paralysis. Its persistence beyond 1 year of age may be due to spasticity of leg and foot muscles. The reflex may also persist in children with birth injuries and delayed development.

Moro's Reflex. This important vestibular reflex was first described by Moro in 1918[57] and well reviewed by Mitchell in 1960.[56] To test Moro's reflex, the patient is placed supine with both upper and lower limbs in full, natural

TABLE 3–9 **Innervation of Muscles Responsible for Movements of the Shoulder Girdle and Upper Extremity**

Muscle	Segmental Innervation	Peripheral Nerve
Trapezius	Cranial XI; C(2)3–4	Spinal accessory nerve
Levator anguli scapulae	C3–4	Nerves to levator anguli scapulae
	C4–5	Dorsal scapular nerve
Rhomboideus major	C4–5	Dorsal scapular nerve
Rhomboideus minor	C4–5	Dorsal scapular nerve
Serratus anterior	C5–7	Long thoracic nerve
Deltoid	C5–6	Axillary nerve
Teres minor	C5–6	Axillary nerve
Supraspinatus	C(4)5–6	Suprascapular nerve
Infraspinatus	C(4)5–6	Suprascapular nerve
Latissimus dorsi	C6–8	Thoracodorsal nerve (long subscapular)
Pectoralis major	C5–T1	Lateral and medial anterior thoracic
Pectoralis minor	C7–T1	Medial anterior thoracic
Subscapularis	C5–7	Subscapular nerves
Teres major	C5–7	Lower subscapular nerve
Subclavius	C5–6	Nerve to subclavius
Coracobrachialis	C6–7	Musculocutaneous nerve
Biceps brachii	C5–6	Musculocutaneous nerve
Brachialis	C5–6	Musculocutaneous nerve
Brachioradialis	C5–6	Radial nerve
Triceps brachii	C6–8(T1)	Radial nerve
Anconeus	C7–8	Radial nerve
Supinator brevis	C5–7	Radial nerve
Extensor carpi radialis longus	C(5)6–7(8)	Radial nerve
Extensor carpi radialis brevis	C(5)6–7(8)	Radial nerve
Extensor carpi ulnaris	C6–8	Radial nerve
Extensor digitorum communis	C6–8	Radial nerve
Extensor indicis proprius	C6–8	Radial nerve
Extensor digiti minimi proprius	C6–8	Radial nerve
Extensor pollicis longus	C6–8	Radial nerve
Extensor pollicis brevis	C6–8	Radial nerve
Abductor pollicis longus	C6–8	Radial nerve
Pronator teres	C6–7	Median nerve
Flexor carpi radialis	C6–7(8)	Median nerve
Pronator quadratus	C7–T1	Median nerve
Palmaris longus	C7–T1	Median nerve
Flexor digitorum sublimis	C7–T1	Median nerve
Flexor digitorum profundus (radial half)	C7–T1	Median nerve
Lumbricales 1 and 2	C7–T1	Median nerve
Flexor pollicis longus	C8–T1	Median nerve
Flexor pollicis brevis (lateral head)	C8–T1	Median nerve
Abductor pollicis brevis	C8–T1	Median nerve
Opponens pollicis	C8–T1	Median nerve
Flexor carpi ulnaris	C7–T1	Ulnar nerve
Flexor digitorum profundus (ulnar half)	C7–T1	Ulnar nerve
Interossei	C8–T1	Ulnar nerve
Lumbricales 3 and 4	C8–T1	Ulnar nerve
Flexor pollicis brevis (medial head)	C8–T1	Ulnar nerve
Flexor digiti minimi brevis	C8–T1	Ulnar nerve
Abductor digiti minimi	C8–T1	Ulnar nerve
Opponens digiti minimi	C8–T1	Ulnar nerve
Palmaris brevis	C8–T1	Ulnar nerve
Adductor pollicis	C8–T1	Ulnar nerve

From Dejong RN: The Neurological Examination, pp 456–457. New York, Hoeber Medical Division, Harper & Row, 1967.

extension. A variety of stimuli can be used to elicit this reflex. Common among the different methods is a sudden extension of the infant's neck. The examiner can lift the infant in the supine position several inches above the examining table with one hand placed under the infant's thoracic spine and the other hand under the back of the head.[5] The hand supporting the head is then suddenly removed, allowing neck extension (Fig. 3–41A). The examiner can also hold the infant in the supine position, supporting the head, back, and legs, then suddenly lower the entire body about 2 feet and stop abruptly. Alternatively, the infant can be gently raised slightly off the table by holding the infant's hands and then quickly releasing them, causing sudden extension of the cervical spine (Fig. 3–41B). The examining physician must handle the infant gently during any of these maneuvers to avoid excessive or disconcerting head and neck movement. The reflex can also be evoked by producing a loud noise (e.g., sharply

TABLE 3–10 **Innervation of Muscles Responsible for Movements of the Lower Extremities**

Muscle	Segmental Innervation	Peripheral Nerve
Psoas major	L(1)2–4	Nerve to psoas major
Psoas minor	L1–2	Nerve to psoas minor
Iliacus	L2–4	Femoral nerve
Quadriceps femoris	L2–4	Femoral nerve
Sartorius	L2–4	Femoral nerve
Pectineus	L2–4	Femoral nerve
Gluteus maximus	L5–S2	Inferior gluteal nerve
Gluteus medius	L4–S1	Superior gluteal nerve
Gluteus minimus	L4–S1	Superior gluteal nerve
Tensor fasciae latae	L4–S1	Superior gluteal nerve
Piriformis	S1–2	Nerve to piriformis
Adductor longus	L2–4	Obturator nerve
Adductor brevis	L2–4	Obturator nerve
Adductor magnus	L2–4	Obturator nerve
	L4–5	Sciatic nerve
Gracilis	L2–4	Obturator nerve
Obturator externus	L2–4	Obturator nerve
Obturator internus	L5–S3	Nerve to obturator internus
Gemellus superior	L5–S3	Nerve to obturator internus
Gemellus inferior	L4–S1	Nerve to quadratus femoris
Quadratus femoris	L4–S1	Nerve to quadratus femoris
Biceps femoris (long head)	L5–S1	Tibial nerve
Semimembranosus	L4–S1	Tibial nerve
Semitendinosus	L5–S2	Tibial nerve
Popliteus	L5–S1	Tibial nerve
Gastrocnemius	L5–S2	Tibial nerve
Soleus	L5–S2	Tibial nerve
Plantaris	L5–S1	Tibial nerve
Tibialis posterior	L5–S1	Tibial nerve
Flexor digitorum longus	L5–S1	Tibial nerve
Flexor hallucis longus	L5–S1	Tibial nerve
Biceps femoris (short head)	L5–S2	Common peroneal nerve
Tibialis anterior	L4–S1	Deep peroneal nerve
Peroneus tertius	L4–S1	Deep peroneal nerve
Extensor digitorum longus	L4–S1	Deep peroneal nerve
Extensor hallucis longus	L4–S1	Deep peroneal nerve
Extensor digitorum brevis	L4–S1	Deep peroneal nerve
Extensor hallucis brevis	L4–S1	Deep peroneal nerve
Peroneus longus	L4–S1	Superficial peroneal nerve
Peroneus brevis	L4–S1	Superficial peroneal nerve
Flexor digitorum brevis	L4–S1	Medial plantar nerve
Flexor hallucis brevis	L5–S1	Medial plantar nerve
Abductor hallucis	L4–S1	Medial plantar nerve
Lumbricales (medial 1 or 2)	L4–S1	Medial plantar nerve
Quadratus plantae	S1–2	Lateral plantar nerve
Adductor hallucis	L5–S2	Lateral plantar nerve
Abductor digiti quinti	S1–2	Lateral plantar nerve
Flexor digiti quinti brevis	S1–2	Lateral plantar nerve
Lumbricales (lateral 2 or 3)	S1–2	Lateral plantar nerve
Interossei	S1–2	Lateral plantar nerve

From Dejong RN: The Neurological Examination, pp 483–484. New York, Hoeber Medical Division, Harper & Row, 1967.

banging the examination table with the palms of the hand on both sides of the infant's head) or with a sudden tap on the infant's abdomen.

The first phase of Moro's reflex consists of sudden abduction and extension of all four limbs and extension of the spine, with extension and fanning of the fingers, except for flexion of the distal phalanges of the index finger and thumb (Fig. 3–41C). This is followed by the second phase, in which there is adduction and flexion of all four limbs, with the arms coming forward over the body in a clasping movement as if the infant were embracing (Fig. 3–41D). The reflex may also be accompanied by crying.

Moro's reflex is present at birth and gradually disappears by 3 to 6 months of age. Various conditions can cause abnormalities of this reflex. It may be decreased when there is severe hypertonicity, because the increased muscle tone prevents full motion of the limbs. Depending on the severity of the hypertonicity, the limbs may move only partially at the height of the reflex, the hands may fail to open, or there may be no response because the limbs are so tightly flexed.

TABLE 3–11 **Normal Times of Appearance and Disappearance of Infantile Reflexes and Reactions**

Reflex or Reaction	Timing
Palmar (hand) grasp reflex	Present in neonates and very young infants; normally disappears between ages 2 and 4 mo
Plantar (foot) grasp reflex	Present in neonates and infants; usually disappears between ages 9 and 12 mo
Moro's reflex	Present at birth; gradually disappears by ages 3 to 6 mo
Startle reflex	Appears at birth; present throughout life
Vertical suspension positioning	Reflex normally disappears after age 4 mo
Placing reaction	Normally present at birth in full-term neonates; upper limb placing usually disappears by ages 2 to 4 mo and lower limb placing by ages 1 to 2 mo; both responses may persist up to age 12 mo or older
Walking or stepping reflex	Normally present at birth; usually disappears by ages 1 to 2 mo
Crossed extension reflex	Present at birth; normally disappears by ages 1 to 2 mo
Withdrawal reflex	Present at birth; disappears between ages 1 and 2 mo
Positive support response/leg-straightening reflex	Present at birth; normally disappears at about 4 mo
Extensor thrust reflex	Present at birth; normally present up to 2 mo
Galant's reflex (trunk incurvation)	Present at birth; disappears at about 2 to 2½ mo
Rotation reflex	Time of disappearance varies
Tonic neck reflexes	Asymmetric reflex present at birth, normally disappears by 4 to 6 mo; symmetric reflex usually present by 5 to 8 mo, often diminished or absent by 12 mo
Landau reflex	Normally present from 6 mo to 24 to 30 mo
Parachute reaction	Appears at about 6 mo; remains throughout life
Neck righting reflex	Normally present from birth to about 6 mo
Body righting reflex	Appears around 6 mo; can disappear any time after 5 yr or persist throughout life
Oral reflexes	Usually disappear at 3 to 4 mo; may be present longer during sleep

Moro's reflex may also be decreased or absent in patients with generalized muscle weakness, marked hypotonicity (e.g., amyotonia congenita), or flaccid paralysis. In premature infants, the limbs tend to fall backward to the table during the adduction phase because of the weakness of their antigravity muscles. The response may be asymmetric if the infant has sustained a peripheral nerve injury (e.g., obstetric brachial plexus paralysis). The reflex may persist after it should have disappeared if there is developmental delay of the CNS (as seen in cerebral palsy).

Startle Reflex. The startle reflex is a mass myoclonic reflex that is normal in infants and young children. It is not the same as Moro's reflex and should not be confused with the latter. The infant is placed supine with all four limbs in natural extension. The reflex is elicited by making a sudden loud noise or by tapping the infant's sternum. The normal response is for the elbows and knees to flex (not extend, as in Moro's response) and the hands to remain closed. The startle reflex appears at birth and is present through life. Its absence indicates severe hypotonia. An asymmetric response may be due to obstetric brachial plexus paralysis.

Vertical Suspension Positioning. The infant is held upright and facing away from the examiner, with the examiner's hands under the axillae for support. Normally, the infant will maintain the head in the midline and flex the legs at the hips and knees. Fixed extension and crossed adduction of the legs (scissoring) indicate spastic paraplegia or diplegia. This reflex normally disappears after 4 months of age.

Placing Reaction. The placing reaction is tested separately for the lower and upper limbs. To elicit the placing reaction for the lower limbs, the examiner supports the patient upright by holding the infant under the axillae with the examiner's thumbs supporting the back of the head and the infant facing away (vertical suspension position). The anterior aspect of the distal tibia or dorsal surface of one foot is then brought against the edge of the examining table (Fig. 3–42A). The infant will spontaneously flex the hip and knee, dorsiflex the ankle, and place the foot on the table, extending the lower limb on active or passive contact of the sole with the table (Fig. 3–42B). The process is then repeated with the other foot.

To elicit the placing reaction for the upper limbs, the infant is held at the waist and facing away from the examiner, and the dorsum of the infant's ulna is placed against the edge of the table (Fig. 3–43A). The infant will respond by flexing the elbow and placing the hand on the table (Fig. 3–43B). In older children, these responses must be differentiated from voluntary placing.

The placing reaction is normally present at birth in full-term neonates. Upper limb placing usually disappears by 2 to 4 months of age and lower limb placing by 1 to 2 months of age, but both responses may persist up to 12 months of age or older. If the reflex is absent at birth, the infant may have neurologic dysfunction.

Walking or Stepping Reflex. The walking or stepping reflex is elicited by supporting the trunk and holding the infant upright. The soles of the feet are pressed (touched) against the examining table or ground, and the child is gently inclined and moved forward (Fig. 3–44A). This automatically initiates alternating flexion and extension of the lower limbs, simulating walking (Figs. 3–44B and C). The response is rhythmic and coordinated, needing only forward movement (no propulsion) for stimulus. This automatic walking reflex should not be confused with mature, independent walking, as there is neither balance nor associated movement of the upper limbs. Automatic reflex walking can only be elicited in forward motion; it does not occur with backward movement.

The walking reflex is normally present at birth and disap-

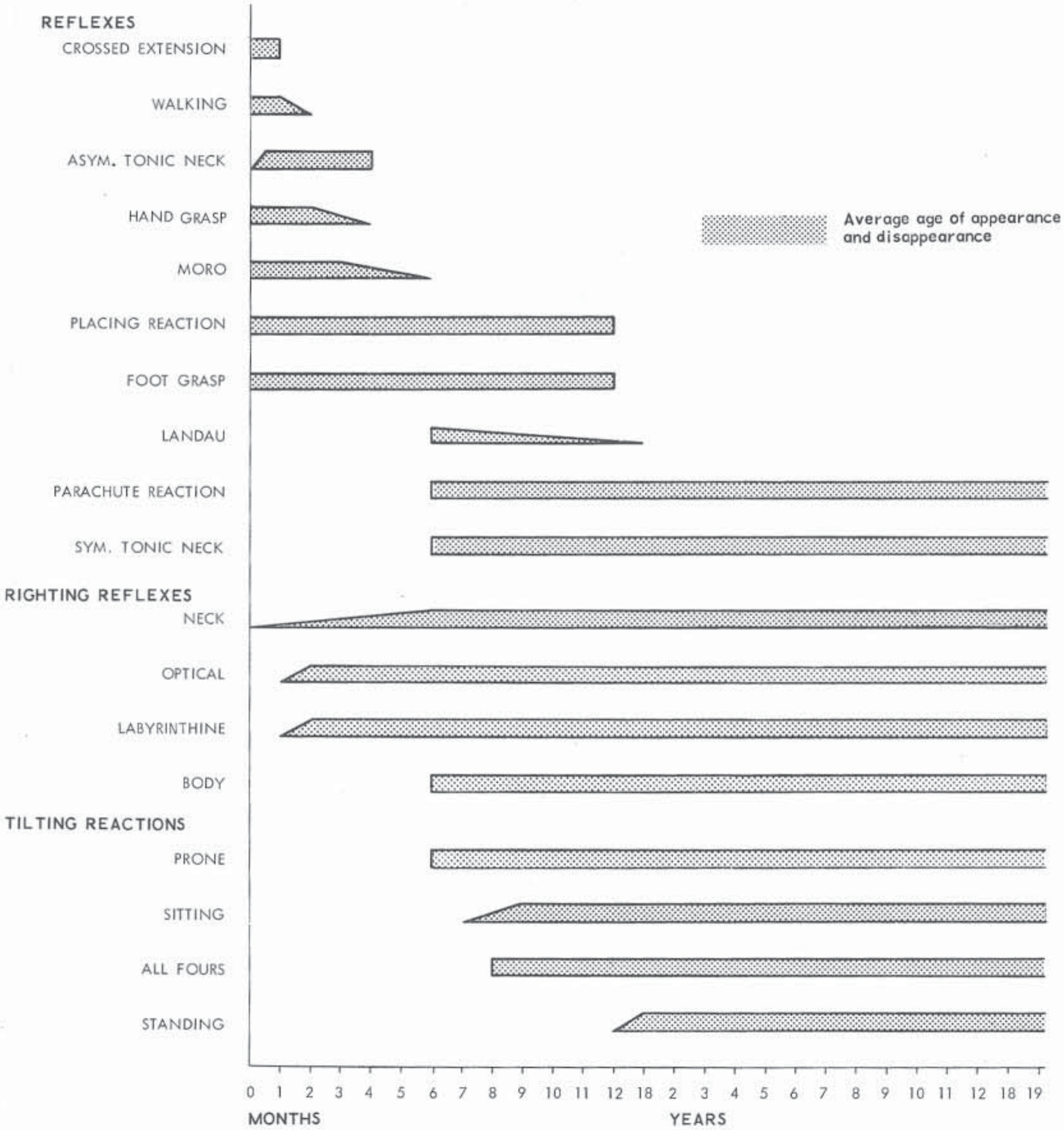


FIGURE 3–38 Reflex maturation chart showing normal timing of appearance and disappearance of infantile reflexes and reactions.

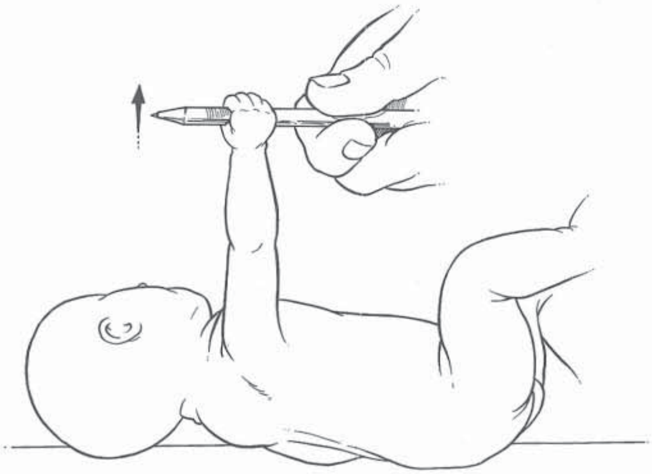


FIGURE 3–39 Palmar (hand) grasp reflex. To elicit the reflex, the examiner places a finger or object into the infant's palm from the ulnar side. If the response is marked, the grip will be strong enough to suspend the infant for a moment.

FIGURE 3–40 Plantar (foot) grasp reflex. When light pressure is applied to the plantar surface of the foot, tonic flexion and adduction of the toes will occur.

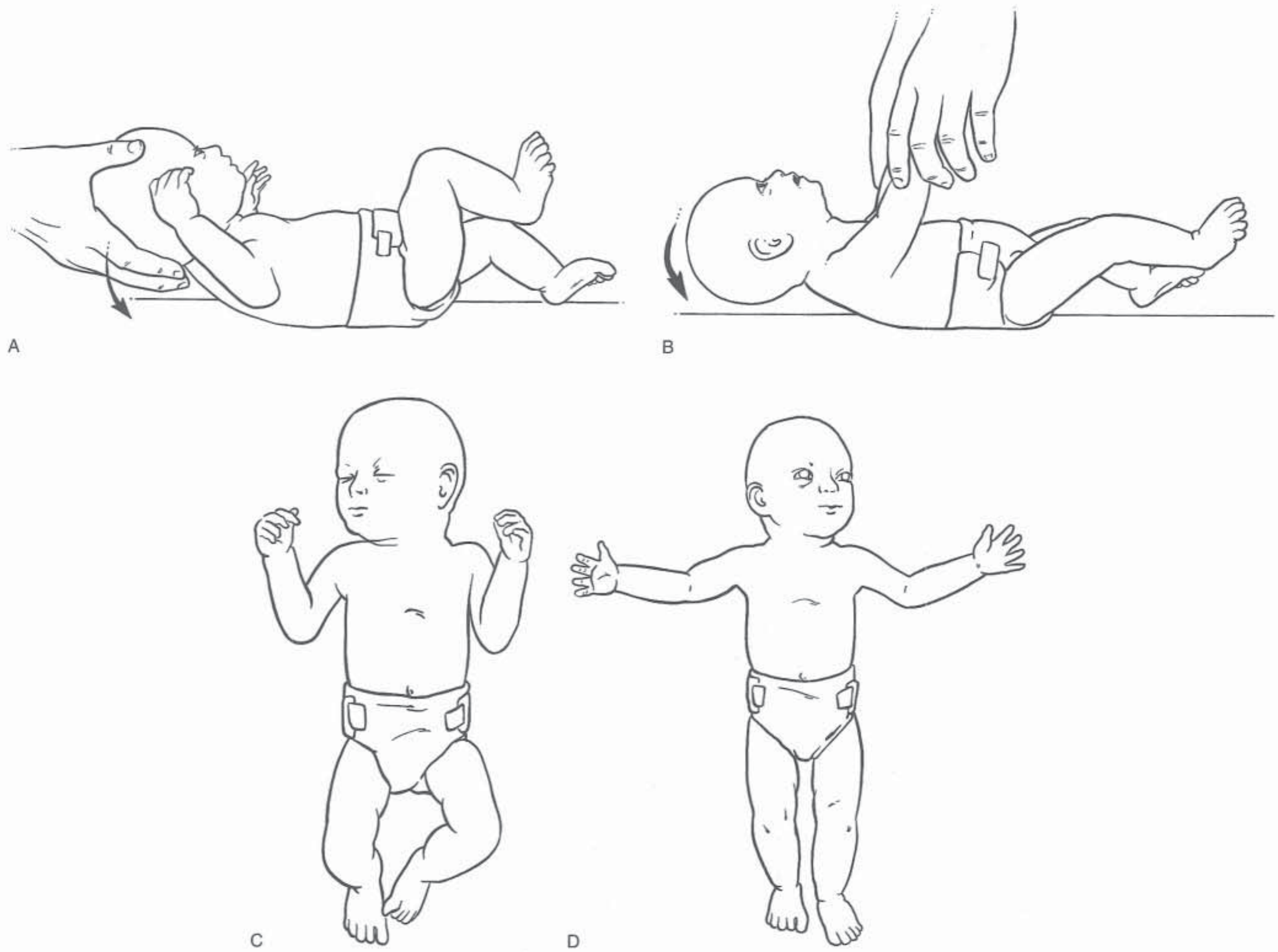


FIGURE 3–41 Moro's reflex. **A,** Sudden removal of hand supporting the infant's head causes extension of the neck. **B,** Holding the infant by the hands and then quickly releasing them also causes extension of the neck. **C,** First phase of a positive response: sudden abduction and extension of all four limbs and extension of the spine. **D,** Second phase: adduction and flexion of all four limbs.

pears by 1 to 2 months of age. Its absence at birth may be due to flaccid paralysis. If the reflex is present after 3 to 4 months of age, the infant may have neurologic impairment.

Crossed Extension Reflex. The infant is placed supine with the lower limbs in midline and the hips and knees extended. The reflex is elicited by holding one lower limb in extension at the knee and applying firm pressure by rubbing or stroking the sole (Fig. 3–45A). The opposite, free hip will initially flex and abduct (Fig. 3–45B), then adduct and extend (Fig. 3–45C), as if the infant were trying to push away from the stimulus. There may be associated fanning of the toes of the stimulated leg. Stimulation of the sole of the foot causes flexion of the ipsilateral limb, moving it away from the stimulus, and extension of the contralateral limb, moving it toward the stimulus. In neonates, a similar response can be elicited by applying strong pressure in the inguinal region, which causes flexion of the ipsilateral limb and extension of the contralateral hip and knee.

The crossed extension reflex, also known as Philippson's reflex, is present at birth and normally disappears by 1 to 2 months of age. If it is absent at birth, the neonate may have flaccid paralysis. Its presence beyond 2 months of age is indicative of a partial or incomplete spinal lesion or neurologic dysfunction.

Withdrawal Reflex. The infant is placed supine with the lower limbs in midline and natural extension. The reflex is elicited by applying a pinprick to the sole of the foot. The infant will withdraw the limb from this noxious stimulus by dorsiflexing the ankle and flexing the hip and knee.

The withdrawal reflex is present at birth and disappears between 1 and 2 months of age. The reflex is weak or absent in infants born with meningomyelocele, and in children with flaccid paralysis due to other intraspinal lesions. Abnormal persistence may be due to spasticity of the lower limbs, as is seen in infants with cerebral palsy.

Positive Support Response/Leg-Straightening Reflex. The infant is held upright in a standing position, with the examiner providing support under the axillae and around the chest. The soles of the infant's feet are pressed to the table or ground several times. When the support response is positive, the lower limbs and trunk will go into extension, the legs thus acting as strong supporting pillars for weight-bearing. This reflex is present at birth and normally disap-

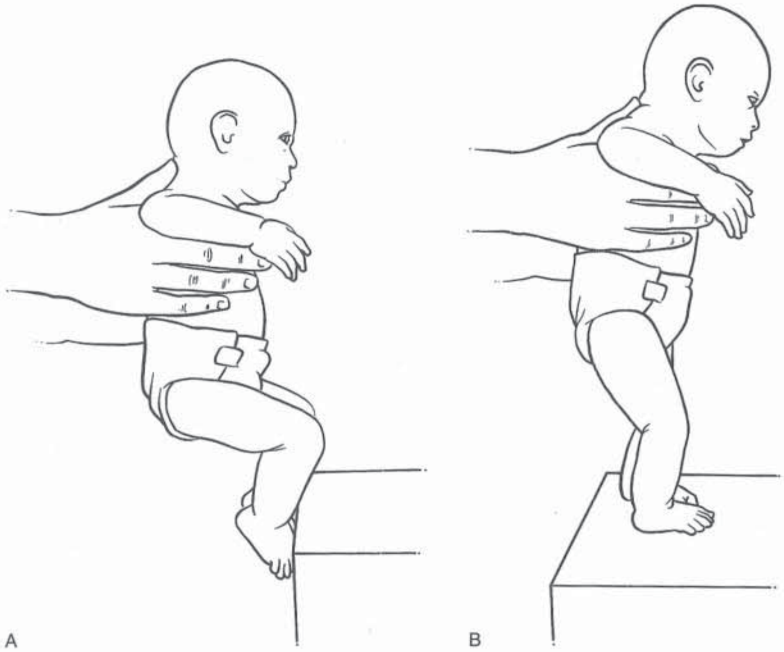


FIGURE 3–42 Placing reaction with lower limbs. **A,** The anterior aspect of the distal tibia or dorsal surface of one foot is brought against the edge of the examining table. **B,** The infant will spontaneously flex the hip and knee, dorsiflex the ankle, and place the foot on the table, extending the lower limb on active or passive contact of the sole with the table.

pears at about 4 months of age so that further motor development can occur. If the reflex persists, reciprocal leg movements cannot appear and the infant will be unable to stand or walk.

Extensor Thrust Reflex. When pressure is applied to the sole of the infant's foot with the lower limb in a flexed position, the infant will suddenly extend the entire leg. This extension is sometimes followed by flexion. This reflex can also be tested by holding the infant by the chest wall and axilla and lowering the infant's feet toward the top of the examining table. When the soles of the feet are pressed against the table, there is progressive extension of the legs from the feet proximally. The extensor thrust reflex is present at birth and normally up to 2 months of age. Its absence may be due to flaccid paralysis. Its presence beyond 2 months of age indicates neurologic dysfunction and developmental delay of the CNS.

Galant's Reflex (Trunk Incurvation). To elicit this reflex, the infant is placed in the prone position and the examiner strikes one side of the lumbar region of the back (between the 10th rib and the iliac crest, approximately 1 cm from the midline along a paravertebral line extending from the shoulder to the buttocks) with the index finger (Fig. 3–46). When the reflex is present, the infant's trunk will curve (flex laterally) toward the stimulated side, with the shoulders and pelvis moving in the same direction. A similar response can be elicited by pricking the outer side of the gluteal area, whereby the trunk will flex to the side stimulated. Galant's reflex is present at birth and disappears at about 2 to $2\frac{1}{2}$ months of age. If the response persists and is dominant unilaterally, the patient may develop scoliosis.

Rotation Reflex. The infant is held upright, supported under the axillae and facing the examiner. The examiner then turns slowly around in one direction and then in the other.

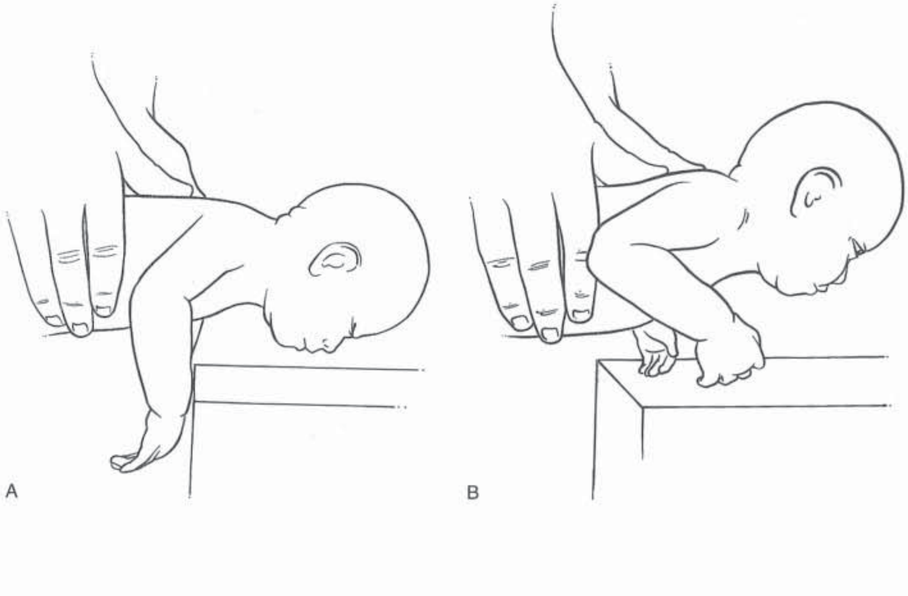


FIGURE 3–43 Placing reaction with upper limbs. **A,** The dorsum of the infant's ulna is placed against the edge of the table. **B,** The infant will respond by flexing the elbow and placing the hand on the table.

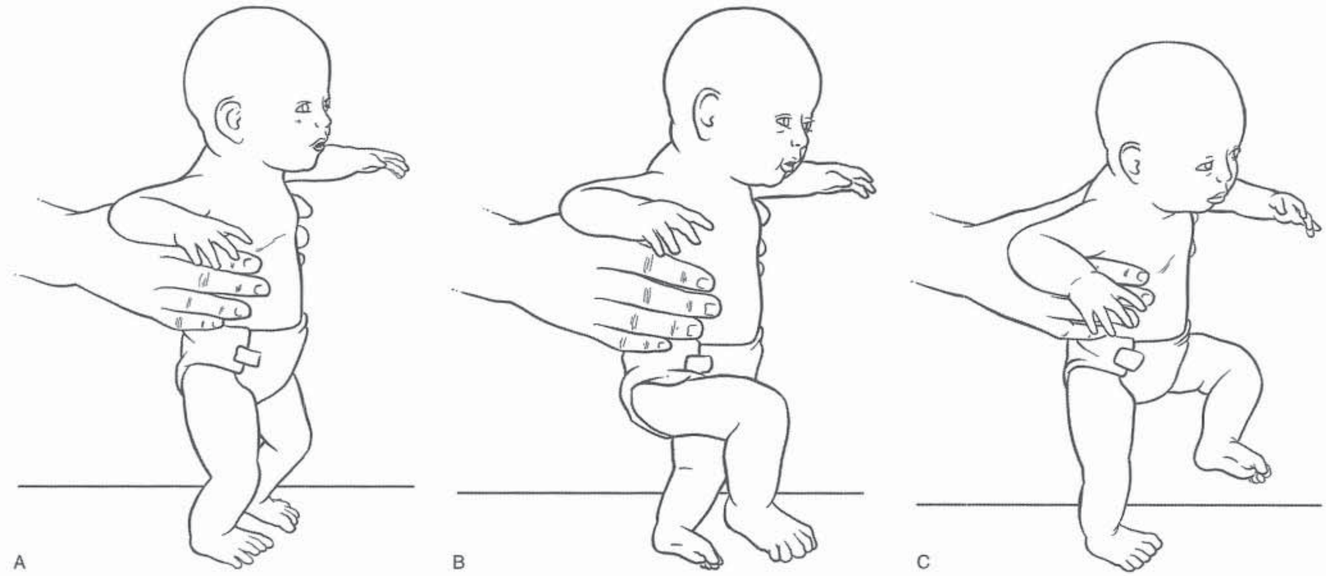


FIGURE 3–44 Walking or stepping reflex. **A,** The soles of the infant's feet are pressed (touched) against the examining table or ground, and the child is gently inclined and moved forward. **B** and **C,** This automatically initiates alternating flexion and extension of the lower limbs, simulating walking.

The infant's head should turn in the same direction as the examiner. This test is also performed by restraining the patient's head with the thumbs as the examiner turns. In this situation, the infant's eyes should turn in the direction that the examiner turns. The time at which this reflex disappears varies.

Tonic Neck Reflexes. There are both asymmetric and symmetric tonic neck reflexes. Of the two, the asymmetric form is tested more often. To test the *asymmetric tonic neck reflex,* the infant is placed in the supine position with the head in midline. To elicit the reflex, the infant's head is turned to one side (without flexion), maintained in that position for 5 to 10 seconds by holding the chin over the shoulder, and then turned to the opposite side. With a positive response, the arm on the side to which the chin is rotated becomes rigid and the elbow goes into extension (the leg on that side may also extend) (Fig. 3–47). On the opposite side (the "occiput" side), the arm (and sometimes the leg) goes into flexion. This is the classically described "fencer's position." The grasp reflex may be more easily elicited on the flexion side.

FIGURE 3–45 Crossed extension reflex. **A,** The reflex is elicited by holding one lower limb in extension at the knee and applying firm pressure by rubbing or stroking its sole. **B,** The opposite, free hip will initially flex and abduct. **C,** This is followed by adduction and extension of the limb.

FIGURE 3–46 Galant's reflex (trunk incurvation). Stimulating one side of the lumbar region of the infant's back causes the trunk to curve (flex laterally) toward the stimulated side.

The asymmetric tonic neck reflex is present at birth and normally disappears by 4 to 6 months of age. Its absence indicates flaccid paralysis or severe hypotonia. The reflex is considered abnormal when it occurs every time it is evoked. In pathologic conditions, such as severe cerebral palsy, the reflex persists and may even increase. Increased extensor tone on the "chin" side and increased flexor tone on the "occiput" side may be the only findings when the positive response is weak.

FIGURE 3–47 Asymmetric tonic neck reflex. The arm on the side to which the infant's chin is rotated becomes rigid and the elbow goes into extension (the leg on that side may also extend). On the opposite side, the arm (and sometimes the leg) goes into flexion.

The *symmetric tonic neck reflex* is tested with the infant resting in the prone position over the examiner's knees (the quadriceps position) (Fig. 3–48A). When the head and neck are extended, the upper limbs extend (or extensor tone increases) while the lower limbs flex (or flexor tone increases) (Fig. 3–48B). When the head and neck are flexed, the upper limbs flex (or flexor tone increases) and the lower limbs extend (or extensor tone increases).

The symmetric tonic neck reflex usually is present by 5 to 8 months of age. If absent, the infant will be unable to assume a four-point kneeling position. There is no absolute time for its normal disappearance; however, it is often diminished or absent by 12 months of age. Its persistence can interfere with alternating lower limb motion and prevent crawling or hinder ambulation. It can also cause adduction and medial rotation, resulting in flexion gait patterns.

Landau Reflex. To test the Landau reflex, the infant is held in the air in the prone position, with the examiner's hand supporting the infant under the abdomen and lower thorax. The infant's body should be parallel with the floor. The examiner should note whether the neck, spine, and hips assume a hyperextended position or whether the limbs hang lifelessly. The head and neck are first passively flexed and then extended, and the respective positions of the limbs and trunk are noted. The Landau reflex is positive when, on passive flexion of the head and neck with the body in the extended position, the trunk and upper and lower limbs go into flexion, and when, on passive extension of the head and neck, the trunk and limbs are brought into the extended position.

This reflex is normally present from 6 months of age to 24 to 30 months of age. Its absence indicates motor weakness. If it persists beyond 30 months of age, the child may have delayed reflex development (which usually interferes with the predominant flexion patterns seen in infants).

Parachute Reaction/Protective Extension of Arms Reflex. The parachute reaction can be tested with the patient prone, sitting, or standing. In the first position, the child is suspended prone in the air by the waist (Fig. 3–49A) and the head is moved suddenly toward the floor by tipping or plunging it downward. With a positive response, the child will immediately extend the arms and wrists forward to protect the head, as if to break the force of the fall (Fig. 3–49B).

In the sitting or standing neutral position, the response is elicited by suddenly tipping or pushing the child backward with enough force to offset balance. The positive response will be a backward extension of both arms, with the fingers extended and abducted and the weight born on the hands. The parachute reaction can be obtained in blindfolded children, as it does not depend on vision.

This reflex appears at about 6 months of age and remains throughout life. Absence of this reflex indicates delayed neurologic development (in infants) or severe neurologic dysfunction.[37,38]

Neck Righting Reflex. To test this reflex, the child is placed in the supine position with the head in midline and all four limbs fully extended. The reflex is elicited by flexing and rotating the head to one side, and maintaining it in this position for about 10 seconds. When the reflex is present,

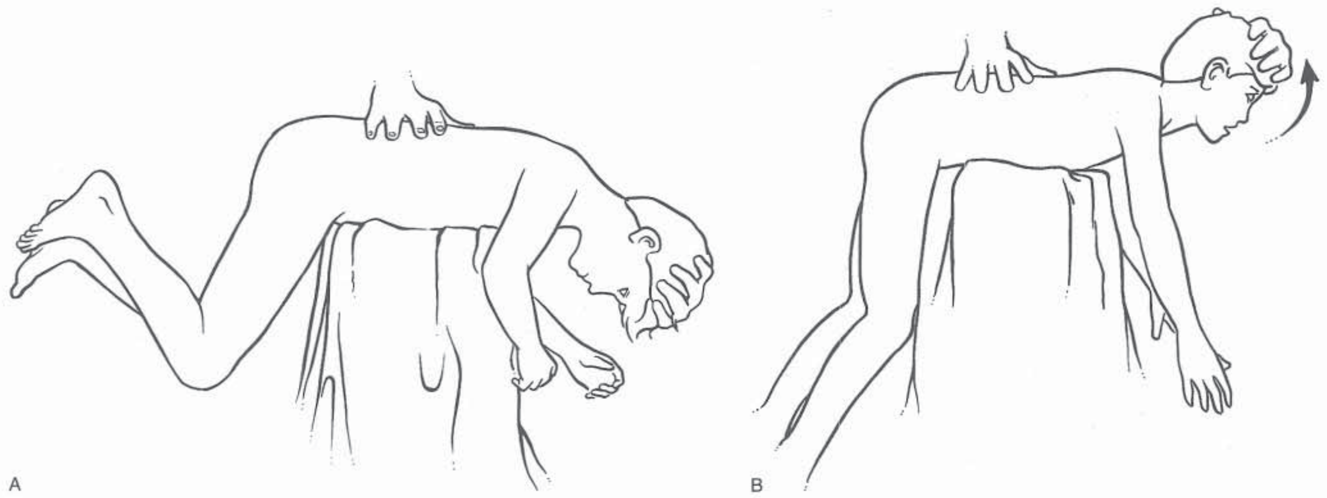


FIGURE 3–48 Symmetric tonic neck reflex. **A,** This reflex can be tested with the child lying prone over the examiner's knee. When the head and neck are extended, the upper limbs extend and the lower limbs flex. **B,** When the head and neck are flexed, the upper limbs flex and the lower limbs extend. Persistence of this reflex after 12 months of age is abnormal.

the child's entire body will rotate in the same direction as the head. When it is absent, the body will not rotate.

The neck righting reflex normally is present from birth to about 6 months. If it is absent after 1 month of age, the infant may have delayed neurologic development. Abnormal persistence after 6 months of age indicates neurologic impairment.

Body Righting Reflex. This reflex also is tested with the child supine, the head in midline position, and all four limbs in extension. The reflex is elicited in the same manner as the neck righting reflex, by flexing and rotating the head to one side and maintaining it in this position for 10 seconds. A positive response in this case, though, is sequential or segmental cephalocaudal rotation of the trunk—first the shoulder rotates, then the trunk, and finally the pelvis (in contrast to the body as a whole, with the neck righting reflex). This reflex appears around 6 months of age (when the neck righting reflex should disappear) and can disappear any time after 5 years of age or persist throughout life.

Oral Reflexes. The *sucking reflex* is elicited by introducing a finger or a nipple into the infant's mouth. The "*rooting*" or "*search*" reflex is a feeding reflex that enables the infant to find the mother's nipple without having to be directed to it.

The infant should be supine, with the head in the midline position and the hands resting on the anterior chest. When the corner of the mouth is lightly stroked with the forefinger, the lower lip on that side is lowered, the tongue moves

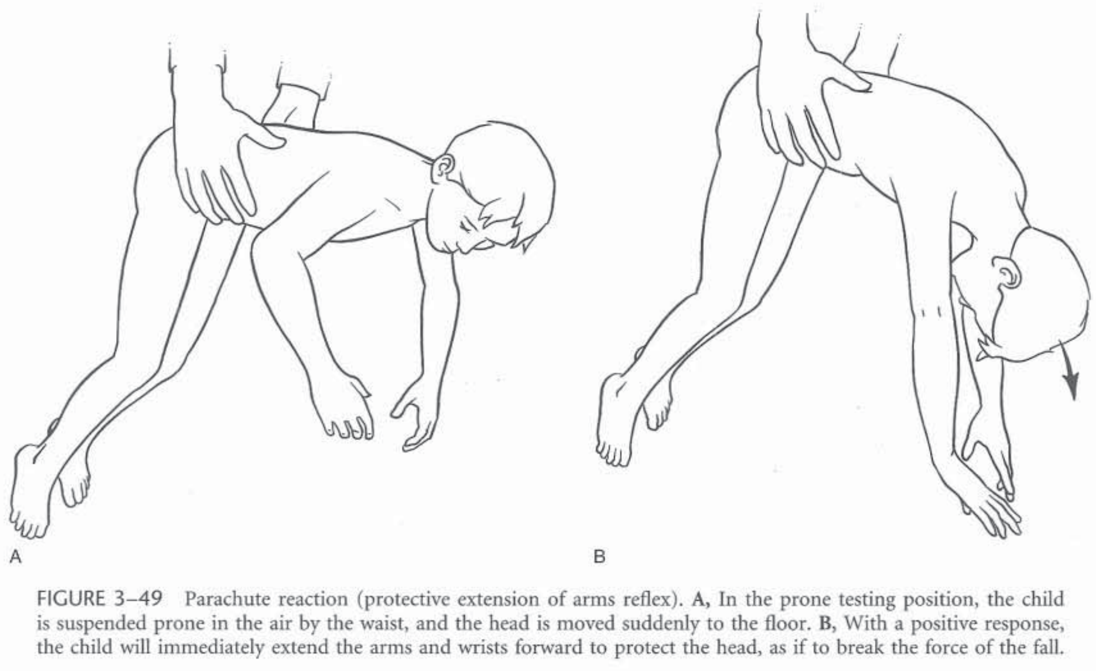


FIGURE 3–49 Parachute reaction (protective extension of arms reflex). **A,** In the prone testing position, the child is suspended prone in the air by the waist, and the head is moved suddenly to the floor. **B,** With a positive response, the child will immediately extend the arms and wrists forward to protect the head, as if to break the force of the fall.

toward it, and the head turns to the stimulated side. When the examiner's finger is moved upward along the oronasal groove, the infant's head extends; when the finger is moved laterally, the head turns to follow it. When the middle of the lower lip is stroked, the lip is lowered, the tongue moves toward it, and the chin drops. If the examiner's finger is moved toward the chin, the mandible is depressed and the neck flexes. When the middle of the upper lip is stroked, the mouth opens and the head extends.

The oral reflexes are best elicited when the infant is hungry, just before the normal feeding time. These oral reflexes are present in all normal full-term neonates. Their absence is indicative of severe developmental impairment or marked prematurity. They usually disappear at 3 to 4 months of age, but may be present longer during sleep.

DEEP TENDON REFLEXES (MUSCLE STRETCH REFLEXES)

The corticospinal pathways are not fully developed at birth; thus, the spinal reflex mechanisms are variable during infancy. The deep tendon reflexes (biceps, triceps, knee, ankle) are assessed by tapping the appropriate tendons.

In the neonate, the examiner can test the biceps by placing the index finger of the examiner's nondominant hand on the tendon and then tapping with a fingertip of the dominant hand. This technique allows for a tactile perception of the quality of the reflex contraction (which can be difficult to observe directly). Tricep reflexes usually are not present until after 6 months of age. The effects of the reflex contraction of the quadriceps and gastrosoleus can be directly observed by tapping the patellar and Achilles tendons with the fingertip. Hyperactive deep tendon reflexes indicate an upper motor neuron lesion.

To test for ankle clonus (alternating contraction and relaxation of the gastrocnemius and soleus muscles), the infant's hip is abducted and flexed and the knee is flexed; the ankle is then quickly but gently dorsiflexed. Although ankle clonus is an abnormal reflex movement that indicates hypertonicity, its presence alone is not a definitive sign of neurologic dysfunction. In general, unsustained ankle clonus of three to six beats is normal,[78] whereas sustained ankle clonus suggests severe CNS disease. Further tests would be required for a diagnosis.

PERIPHERAL REFLEXES/ABDOMINAL REFLEXES

Babinski's reflex is elicited by applying firm, steady, slow strokes with an object such as a tongue blade along the lateral aspect of the sole of the foot in a posterior-to-anterior direction. The stimulus should not be painful. A normal response is withdrawal of the foot with plantar flexion of the toes. A positive response is a slow, tonic hyperextension of the great toe. The other toes may also hyperextend or they may slowly spread apart (fanning). Babinski's reflex is present in some normal neonates (less than 10 percent) and may persist for as long as 2 years. A hyperactive or persistent Babinski's response may indicate an upper motor neuron lesion.

Hoffmann's reflex is elicited by flicking the nail of the infant's second or third finger with the examiner's nail. This should cause flexion of the distal phalanx of the thumb. There is usually no response or minimal response in normal children. A brisk or asymmetric response may be seen in patients with impaired corticospinal tract function.

The *cremasteric reflex* is elicited in male patients by stroking the inner portion of the thigh in a distal-proximal direction. This maneuver should result in symmetric contraction of the scrotum. Absence or asymmetric response also suggests corticospinal tract involvement.

Abdominal reflexes are stimulated by gently stroking the abdomen. The strokes should go in a lateral-to-medial direction and be directed at the umbilicus. The examiner should start just above the umbilicus, then move laterally to the umbilicus, and finally stroke just below the umbilicus. The reflexes should be present bilaterally. Unilateral absence usually is associated with acquired corticospinal impairment, such as syringomyelia of the spinal cord.

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APPENDIX 3–1 **Texas Scottish Rite Hospital for Children Initial History and Physical Examination Form**

- Name of patient • Chart number • Date of visit
- Chief complaint
- Present illness
- Past history (significant findings appropriate to age of patient)
  - Pregnancy, labor, delivery, neonatal history
  - Immunizations
  - Previous surgery
  - Usual childhood illnesses
- Social history
  - Emotional status
  - Behavioral/activities of daily living
  - Educational status
- Review of systems
  - Physical therapy, occupational therapy, and equipment presently used by patient
  - Allergies
  - Present medications
  - Growth and development
- Family history
- Physical examination
  - Height ◦ Blood pressure
  - Weight ◦ Temperature
  - Respiration ◦ Pulse
  - HEENT ◦ Thorax and chest
  - Neck ◦ Abdomen
  - Heart
- Neurologic examination
  - Mental status ◦ Motor and DTRS
  - Cranial nerves ◦ Sensory
  - Cerebellar
- Muscle examination
  - Atrophy ◦ Strength ◦ Contractures
- Upper extremities examination
- Lower extremities examination
  - Ambulatory status
  - Leg lengths: Right and left
  - Hips: Right and left
    A. External rotation
    B. Internal rotation
    C. Flexion
    D. Extension
    E. Abduction
    F. Adduction
  - Knees: Right and left
    A. Flexion
    B. Extension
  - Ankles: Right and left
    A. Plantar flexion
    B. Dorsiflexion
  - Feet: Right and left
    A. Eversion
    B. Inversion
  - Long bones
- Spine/pelvis examination
- Impression
- Plan (Course of action to include family's and/or guardian's expectations for and involvement in the assessment, treatment, and continuous care of the patient.)

Adapted by John G. Birch, M.D.

Left				Trunk and Legs	Peripheral Nerve	Right			
				Date					
				Sternocleidomastoid C1–4					
				Neck flexors C1–8					
				Neck extensors C1–8; T1					
				Back extensors T1–12; L1–5; S1–3					
				Upper rectus abdominis T5–12					
				Lower rectus abdominis T5–12					
				External oblique T5–12					
				Internal oblique T7–12					
				Iliopsoas L(1), 2, 3, 4	Lumbar plexus, Femoral				
				Sartorius L2, 3, (4)	Femoral				
				Hip adductors L2, 3, 4	Obturator				
				(Adductor magnus L2–5; S1)					
				Gracilis L2, 3, 4					
				Quadriceps L2, 3, 4	Femoral				
				Tensor fascia lata L4, 5; S1					
				Gluteus medius L4, 5; S1	Superior gluteal				
				Hip medial rotation L4, 5; S1					
				Extensor digitorum longus L4, 5; S1	Peroneal				
				Peroneus longus L4, 5; S1	Superficial Peroneal				
				Peroneus brevis L4, 5; S1					
				Extensor digitorum brevis L4, 5; S1					
				Extensor hallucis longus L4, 5; S1	Deep peroneal				
				Anterior tibialis L4, 5; S1					
				Hip lateral rotation L4, 5; S1, 2	Sacral plexus obturator				
				Semitendinosus L4, 5; S1, 2					
				Semimembranosus L4, 5; S1, 2	Sciatric				
				Gluteus maximus L5; S1, 2	Inferior gluteal				
				Biceps femoris L5; S1, 2, 3	Sciatic				
				Gastrocnemius S1, 2					
				Soleus L5; S1, 2					
				Posterior tibialis L(4), 5; S1					
				Flexor digitorum longus L4, 5; S1 (2)	Tibial				
				Flexor digitorum brevis L4, 5; S1					
				Lumbricals L4, 5; S1, 2					
				Flexor hallucis longus L4, 5; S1, 2					
				Flexor hallucis brevis L4, 5; S1, 2					

NOTES:

KEY:
- 0 = Absent
- (1) T = Trace, mere tension on palpation
- P− = Poor minus, beginning motion
- (2) P = Poor, full range, gravity-eliminated
- P+ = Poor plus, begin motion antigravity
- F− = Fair minus, almost full range antigravity
- (3) F = Fair, full range antigravity
- F+ = Fair plus, full range, minimal resistance
- G− = Good minus
- (4) G = Good, full range, moderate resistance
- G+ = Good plus
- (5) N = Normal, maximum resistance

Appendix continued on following page

APPENDIX 3–2 **Manual Muscle Tests of the Lower and Upper Extremities** *Continued*

Left				Upper Extremities/Shoulders	Peripheral Nerve	Right			
				Upper trapezius C.N.XI C2, 3, 4	Accessory, ventral ramus 2, 3, 4				
				Middle trapezius C.NXI C2, 3, 4					
				Lower trapezius C.NXI C2, 3, 4					
				Rhomboids C3, 4, 5	Cervical, dorsal scapular				
				Anterior deltoid C5, 6	Axillary				
				Middle deltoid C5, 6					
				Posterior deltoid C5, 6					
				Shoulder external rotators C(4), 5, 6	Suprascapular, axillary				
				Shoulder internal rotators C5, 6, 7	Upper and lower subscapular				
				Pectoralis major:	Lateral pectoral				
				Clavicular head C5, 6, 7 Sternal C6, 7, 8; T1	Lateral and medial pectoral				
				Serratus anterior C5, 6, 7, 8	Long thoracic				
				Latissimus dorsi C6, 7, 8	Thoracodorsal				
				Biceps C5, 6	Musculocutaneous				
				Brachioradialis C5, 6	Radial				
				Supinator C5, 6, (7)					
				Triceps C6, 7, 8; T1					
				Pronator teres C6, 7	Median				
				Pronator quadratus C7, 8; T1					
				Extensor carpi radialis longus C5, 6, 7, 8	Radial				
				Extensor carpi radialis brevis C5, 6, 7, 8					
				Extensor carpi ulnaris C6, 7, 8					
				Extensor digitorum 1 C6, 7, 8					
				2 C6, 7, 8					
				3 C6, 7, 8					
				4 C6, 7, 8					
				Extensor pollicis brevis C6, 7, 8					
				Extensor pollicis longus C6, 7, 8					
				Abductor pollicis longus C6, 7, 8					
				Flexor carpi radialis C6, 7, 8	Median				
				Opponens pollicis C6, 7, 8; T1					
				Abductor pollicis brevis C6, 7, 8; T1					
				Flexor digitorum superficialis 1 C7, 8; T1					
				2 C7, 8; T1					
				3 C7, 8; T1					
				4 C7, 8; T1					
				Flexor pollicis brevis C6, 7, 8; T1	Median, ulnar				
				Flexor pollicis longus C(6), 7, 8; T1	Median				
				Flexor digitorum profundus 1 C8; T1					
				2 C8; T1					

APPENDIX 3–2 **Manual Muscle Tests of the Lower and Upper Extremities** *Continued*

Left				Upper Extremities/Shoulders	Peripheral Nerve	Right			
				3 C7, 8; T1	Ulnar				
				4 C7, 8; T1					
				Flexor carpi ulnaris C7, 8; T1					
				Palmaris longus C(6), 7, 8; T1	Median				
				Lumbricals 1 and 2 C(6), 7, 8; T1					
				Lumbricals 3 and 4 C(7), 8; T1	Ulnar				
				Dorsal interossei C8; T1					
				Palmar interossei C8; T1					
				Adductor pollicis C8; T1					
				Abductor digiti minimi C(7), 8; T1					
				Opponens digiti minimi C(7), 8; T1					

NOTES: