BMJ Best Practice

Torsion of the lower limb in children

Straight to the point of care

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Summary

Lower-extremity torsional abnormalities are common in children. Commonly attributed to femoral or tibial torsion, soft-tissue contractures, abnormal muscle tone, hindfoot varus/valgus, forefoot adduction/abduction, or a combination of these.

Clinical exam measuring the rotational profile and comparing these values to normal values can determine causes of malalignment.

Torsional variations (version) are defined as alignment that is within 2 standard deviations (SDs) of the mean and account for most rotational problems. Torsional deformities are defined as abnormalities outside the normal range of 2 SDs.

Torsional problems are commonly phenotypic variations that are considered statistically normal, although perhaps not ideal or desirable to parents. Most will spontaneously resolve with growth and development, and have no adverse effect on function.

Femoral and tibial torsion deformities in healthy children who fall outside the normal range of 2 SDs are managed with parental reassurance and education. Arrangements for regular follow-up should be provided. Corrective shoe wedges, night splints, twister cables, and physical therapy have not been shown to alter the natural history or ensure normal gait.

In otherwise healthy children, operative treatment consisting of derotational osteotomy is rarely indicated. Considered only for severe tibial rotation that does not correct by age 4 years and femoral malrotation that does not correct by age 8 years.

In patients with neuromuscular disease, such as cerebral palsy or myelomeningocele, deformities may persist or worsen with time. If left untreated, these deformities may contribute to inefficient gait in ambulatory patients and interfere with sitting posture in wheelchair users.

Definition

Lower-extremity torsional problems commonly present in the first decade of life with parental complaints about intoeing or out-toeing. Intoeing refers to medial (internal) rotation of the foot relative to the direction in which the child is walking or running; out-toeing refers to lateral (external) rotation of the foot. Torsion results from a summation of anatomic axial (transverse) plane tilt or twist between the ends of the bones (i.e., version), capsular laxity or tightness, and muscular control during growth.[1]

Epidemiology

Large clinical series of healthy children reveal that lower-limb rotational alignment varies widely throughout childhood.[2] [3] [4] [5] In the absence of neuromuscular disease, femoral anteversion and tibial torsion are within normal values in 84% to 98% of the population, regardless of age or sex.[5] Although most torsional problems are normal variations, they cause concern in parents and are among the most common reasons for a pediatric orthopedic referral from a primary care pediatric provider.[6] Taking into account the various methods to measure limb rotation through physical examination (primarily the rotational profile) and subtle population differences, torsional deformities by definition fall outside 2 standard deviations from the mean of normative values of the torsional profile, thereby including about 5% of the population.[1] [2] [5] [7] [8] [9] That is not to imply that these patients have some degree of disability, or that patients with borderline values do not. Torsional problems are common in infants and toddlers, and rare in adolescents.

Common abnormalities include: 1) normal femoral anteversion and internal tibial torsion - seen in 2% to 9% from a mean 3 to 8 years old; and 2) increased femoral anteversion and normal tibial torsion - seen in 1% to 9% of children from a mean 6 to 9 years old, and higher in females at any age.

Overall, intoeing is more common than out-toeing. In early infancy, inward rotation of the feet is most likely due to metatarsus adductus or, less commonly, hallux varus. In the toddler, intoeing is commonly due to medial tibial torsion. Intoeing in early childhood and adolescence (especially in girls) is usually due to medial femoral torsion. Torsional deformities are frequent and more often severe in patients with neuromuscular conditions.[10] [11] [12] [13] [14] [15]

Etiology

Torsional variations of the lower extremity are rotational malalignments that fall within 2 standard deviations (SDs) of the mean.[2]

Torsional deformities are defined as rotational abnormalities outside the normal range of 2 SDs. Deformities are caused by:

- Genetics: similar to other congenital deformities
- Intrauterine positioning: abnormal shaping of structures caused by mechanical forces. These are deformations distinguished from dysplasias (which are genetic or cellular abnormalities that result in structural abnormalities).
- Muscle action: abnormalities in muscle function and tone (e.g., cerebral palsy, myelomeningocele, polio). These strongly affect torsional development during growth.[13] [16] [17] [18] [19] [20]

These factors can cause torsional deformities at any of 3 levels of the lower extremity: foot, tibia, and femur.[2] They often exist together. Excessive pelvic rotation can also contribute to gait abnormalities, especially in children with cerebral palsy. Most rotational problems in normal infants and children are physiologic or postural problems. Medial femoral torsion (i.e., excessive femoral anteversion) is an abnormal amount of version between the axes of the femoral neck and the femoral condyles. Increased femoral anteversion allows increased hip medial rotation.[21] Medial femoral torsion (MFT) is associated with sitting in the W position, ligamentous laxity, and conditions such as developmental dysplasia of the hip, cerebral palsy, and hypotonia.[22]

Photo of a child sitting in the W position

From the collection of Tamir Bloom, MD

MFT is the most common cause of intoeing in children older than 6 years.[23] Medial rotation of the hip decreases through adolescence, with correction of intoeing by late childhood in most.[1] [24]

Intoeing caused by medial tibial torsion (MTT) most often is a variation during normal development. MTT is the most common cause of intoeing in children younger than 5 years.[23] However, many children, regardless of age, will demonstrate a combination of MTT and MFT as the cause of their intoeing.[23] Intoeing caused by metatarsus adductus (MA) is hypothesized to be due to abnormal intrauterine mechanical forces acting on the foot. Intoeing seen in clubfoot is a congenital deformity with a foot that is turned inward and points downward. It may be idiopathic or associated with myelomeningocele, arthrogryposis, and other syndromes. Although a genetic predisposition exists for torsional abnormalities, no single cause has been identified. Skewfoot may be caused by improper casting of metatarsus adductus. Most cases occur due to an unknown cause.

Out-toeing caused by lateral femoral torsion (LFT) is commonly from persistent hip abduction contractures that develop in utero. Like medial tibial torsion and metatarsus adductus, abduction contractures usually improve during the first year of walking. One in 5 fetuses is positioned with the lower limbs in external rotation leading to lateral tibial torsion and calcaneovalgus feet. Slipped capital femoral epiphysis (SCFE) is a displacement of the proximal femoral epiphysis around the axis of the femoral metaphysis. This results in an external rotation deformity of the affected lower extremity.

Brain-injured children (e.g., cerebral palsy) have loss of selective muscle control, difficulties with balance, and abnormal muscle tone (primary abnormalities). Torsional deformities develop because the effects of brain injury impose abnormal forces on both muscle and bone. Skeletal deformities may emerge gradually, directly proportional to the rate of skeletal growth.

Pathophysiology

Intoeing

- Medial (internal) tibial torsion (MTT): if severe, gait may be compromised by disrupting shock absorption of the foot during loading response and may compromise limb clearance in the swing phase.[25] [26] Quantitative gait analysis studies of patients with extreme intoeing gait because of MTT have demonstrated increased varus loading of the knee during stance phase, in addition to other primary and compensatory gait deviations.[26] [27] [28] Longstanding severe MTT, related dynamic gait deviations, and associated abnormal loading may be associated with degenerative arthritis of the knee in adults, although the nature of this association is not clear.[26] [27] [29] [30] [31] [32]
- Medial (internal) femoral torsion (MFT): in utero femoral anteversion is about 55°. As a child begins to walk, the hip extends and the anterior iliofemoral ligament stretches over the proximal femur, pushing it backward.[33] This mechanism remodels the proximal femur. Femoral anteversion measures on average 10° to 15° by adulthood. Ligamentous laxity or neuromuscular conditions may have insufficient tension to bring about normal remodeling, resulting in persistent fetal alignment.[34] Limited remodeling of the proximal femur is common in cerebral palsy due to delayed onset of walking and abnormal muscle forces. When walking does begin, the hips are flexed. These factors weaken the iliofemoral ligament tension promoting anteversion. To seat the femoral head in the acetabulum, children walk with the femur in internal rotation, which results in excessive internal rotation of the entire lower limb.[33] Increased femoral anteversion can occur from torsional loading of the femur in the W sitting position. This position may place an increased torsional load on the femur.
- Metatarsus adductus (MA): abnormalities in bony anatomy, such as a deformity of the medial cuneiform, and muscle imbalance or contracture have been suggested.
- Skewfoot: this is a complex deformity of the foot composed of forefoot adduction, midfoot abduction, and hindfoot valgus.
- Clubfoot: this is a rigid deformity consisting of ankle equinus, heel varus, and midfoot and forefoot adductus.
- Blount disease: infantile type (0-4 years old) is a nonphysiologic form of genu varum and MTT caused by a growth disorder of the medial proximal tibia. Deformity is restricted to the proximal tibia and is associated with early walking and obesity. Adolescent type (after age 9 years) shares similar pathophysiology with the infantile type with excessive loads on a varus knee resulting in abnormal growth of the proximal tibial physis. Unlike the infantile type, deformity may also involve the distal femur.

Out-toeing

- Lateral (external) tibial torsion (LTT): if severe, may compromise the stability and lever function of the foot during mid and terminal stance phase of the gait cycle.[35]
- Lateral (external) femoral torsion (LFT): intrauterine positioning of the legs causes lateral rotation hip (abductor) contractures, which result in increased hip external rotation relative to internal rotation and apparent out-toeing in infancy.[3] [36] This usually resolves with early walking.[37]
- Slipped capital femoral epiphysis (SCFE): the femoral neck slips anteriorly and laterally through the physis (growth plate) resulting in an apparent posterior shift of the epiphysis. Increased hip external rotation, decreased hip internal rotation, and increased foot progression angle, as well as other anatomic, clinical, and gait abnormalities, are associated with deformity of the proximal femur. Functional abnormalities may improve after treatment and recovery, and are influenced by severity of residual anatomic deformity.[38] [39]

- Flexible flat feet: this is a normal variation of foot alignment in early childhood, with spontaneous resolution in the first decade of life in nearly all children. Arch height is determined by the bone-ligament complex of the foot and is not influenced by shoe wear.

Effect of torsion on the patellofemoral joint

- Bone alignment is one factor that may contribute to patellofemoral joint mechanics.[40] Abnormal limb alignment in the axial plane may alter the balance of body-weight transfer to the ground, overloading biologic tissues (ligaments, articular cartilage, bone, muscle, and tendon).
- Greater-than-normal internal knee rotation during gait, due to either excess femoral anteversion or lateral tibial torsion, or both, increases the lateral patellofemoral joint compression forces and the strain on the medial patellofemoral ligaments. If severe enough, the physiologic threshold of biologic tissues may be exceeded, producing anterior knee pain, patellar instability, or knee osteoarthrosis in later life.[29] [30] [31] [41] [42] [43] This is called miserable malalignment syndrome.[44]

Deformities in children with neuromuscular disease

- Torsional deformities arise because of abnormal forces acting on the growing skeleton by the effects of the primary brain injury.[33] Bones fail to mold, remodel, or model normally with growth.
- Torsional malalignment is a type of lever-arm dysfunction. Improper transverse plane orientation of the bone causes pathologic gait. Bones are levers, rigid bodies on which a load and force act. Their purpose is to produce a mechanical advantage over the load or rapid motion of the load. Malrotated levers produce pathologic dysfunction by:

    1. Reduction of the magnitude of moments, reducing the ability of muscles to rotate joints of the limb. A moment is the rotatory impetus occurring at a pivot point (fulcrum) generated by forces acting at a distance of a lever arm.
    2. Introduction of secondary moments that alter leverage necessary for normal gait, and promoting further deformities of the long bones by applying abnormal stresses on plastic, growing bones.

Classification

Direction of deformity[1]

Clinical assessment of the direction of lower-extremity rotational alignment is classified as follows.

- Intoeing: the long axis of the foot is internally (medially or toward midline) rotated to the line of progression when walking or running.
- Out-toeing: the long axis of the foot is externally (laterally or away from midline) rotated to the line of progression when walking or running.

Case history

Case history #1

A 2-year-old boy is brought to the orthopedic clinic by his mother, who is concerned that her son keeps falling down and "walks with his feet turning in." His mother has noticed this for the past year. The toddler was recently seen by his pediatrician, who thought that his problem was probably normal but suggested evaluation by an orthopedic specialist. His mother anxiously asks if he needs braces. She recalls that her aunt needed leg braces as a child, but is unsure what the problem was that was being treated. The obstetric history is unremarkable and his developmental milestones are normal.

Case history #2

A 5-year-old girl is referred to the orthopedic clinic with a history of walking with her toes pointing inward. Her parents are concerned that the intoeing has become worse over the past year. The mother has tried encouraging her child to walk with feet turning out with no improvement in her gait and she insists that something be done. The mother describes having had the same problem as a child. The child is able to sit in the W position.

Photo of a child sitting in the W position

From the collection of Tamir Bloom, MD

The obstetric history was unremarkable and her developmental milestones were normal.

Other presentations

Children may develop chronic complaints of anterior knee pain, and be unable to continue sporting activities because of pain. Pediatricians may diagnose chondromalacia patellae, with nonsteroidal analgesics providing minimal relief of symptoms. Pain may be exacerbated by physical activities. Parents may describe having the same problem when they were children, in addition to having their patella dislocated multiple times during later life, which has limited physical activities. While standing, the child's patella may point medially (sometimes described as cross-eyed or squinting patella). The child may run awkwardly, described as an eggbeater running style.

Approach

Differences in foot appearance and position noticed by parents most often reflect variations of normal physiologic development.[46] Unfamiliarity with normal lower-extremity growth and development, and desire for normal alignment in their children, may explain parents' concern and motivation to seek medical advice. Accurate diagnosis of torsional problems involves understanding the reason for consultation, taking parents' concerns seriously, taking a detailed history of the problem, performing a screening exam to rule out pathologic causes, and measuring severity with a rotational profile. Radiographic evaluation is rarely indicated unless a pathologic condition is suspected.

History

Evaluation begins with identifying the reason for consultation and having the parents describe the deformity and their concerns, expectations, and goals. Families may describe an angular deformity rather than a torsional problem. They may think that their child's abnormality may persist or cause long-term disability as they get older, or they may desire braces or special shoes to treat the problem. Practitioners should attempt to acknowledge the parents' concerns. Questions should be asked about the initial time of recognition of the problem, asymmetry, changes during that time interval, aggravating factors, any prior treatment, and family history of similar problems or inheritable conditions (e.g., vitamin D-resistant rickets, achondroplasia, mucopolysaccharidoses, or skeletal dysplasias). Out-toeing in a newborn is usually due to lateral rotation contractures at the hips, medial tibial torsion (MTT) usually presents in toddlers, and medial femoral torsion (MFT) usually presents at age 3 to 6 years. Parents should be asked about the child's sitting and sleeping habits. MTT is commonly associated with sitting on the feet, while MFT is associated with sitting in the W position. A complete maternal pregnancy, birth, and developmental history should be obtained. Standard developmental milestones (sitting, walking, talking, etc) should be determined. Infants usually sit by 8 months and walk independently by 12 to 18 months. A mature or adult walking pattern develops by 7 years. Pain of new onset or recent worsening, falling, tripping, delay in walking, tiring easily when walking, and limp may indicate an underlying disorder.

Miserable malalignment syndrome is typically seen in an older child with knee pain or instability. Infantile Blount disease is typically seen in a toddler >18 months old with varus angulation and medial tibial torsion. Obesity (>95% for the age) is typical. Early walking (before age 1 year) may be noted. The family history may be positive for Blount disease. In adolescent Blount disease, black males in the US are typically affected. Obesity is often present and medial knee pain may be noted.

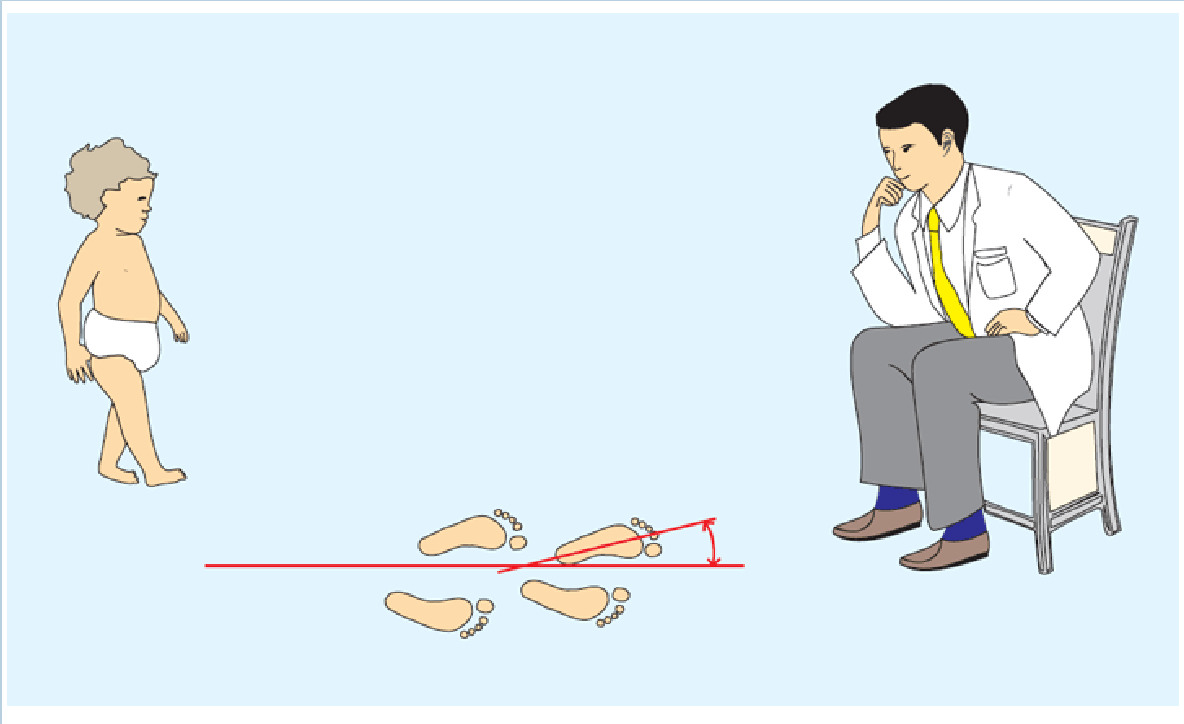
Clubfoot is typically identified at birth. Skewfoot is typically identified at birth or may be iatrogenic following treatment of metatarsus adductus and clubfoot deformities.

Physical exam

Routine musculoskeletal screening exam should be performed before focusing on the rotational problem. A simple 18-step exam described by the Easter Seal Society should be performed on every child, even if parental concerns seem trivial.[47] This standard physical exam evaluates gait, coordination, balance, muscle tone, static deformities, and/or muscle contracture at each joint; torsional and other deformities of bone; and joint laxity. Tripping, falling, and shoe wear problems should be examined. Hip dysplasia or mild diplegia or hemiplegia related to cerebral palsy may present as torsional problems. Slipped capital femoral epiphysis should be considered in any older child or adolescent with complaints of knee, hip, or groin pain; gait abnormality; or asymmetric hip range of motion. Legg-Calve-Perthes disease may also be considered in any child with a limp, hip or groin pain, or asymmetric hip range of motion.

The key to establishing a diagnosis in torsional deformities is determining and recording a rotational profile, which uses anatomic landmarks around the knee, ankle, and foot.[1] [2] [48] The rotational profile includes measurements of:

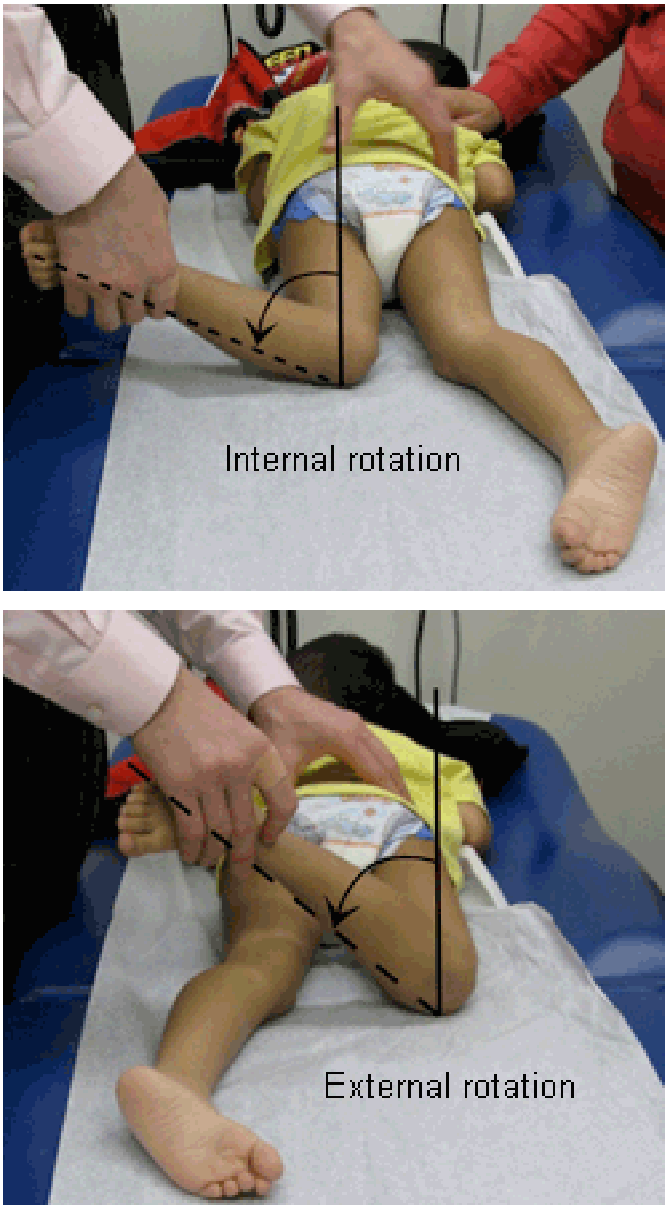
- Foot progression angle during gait



Foot progression angle (FPA) assessed while watching the child walk. FPA is formed by a line drawn in direction of walking and a line from the longitudinal axis of the foot. FPA is summation of torsional alignments of femur, tibia, and foot. Intoeing is designated as a negative number and out-toeing a positive number

From the collection of Lynn T. Staheli, MD

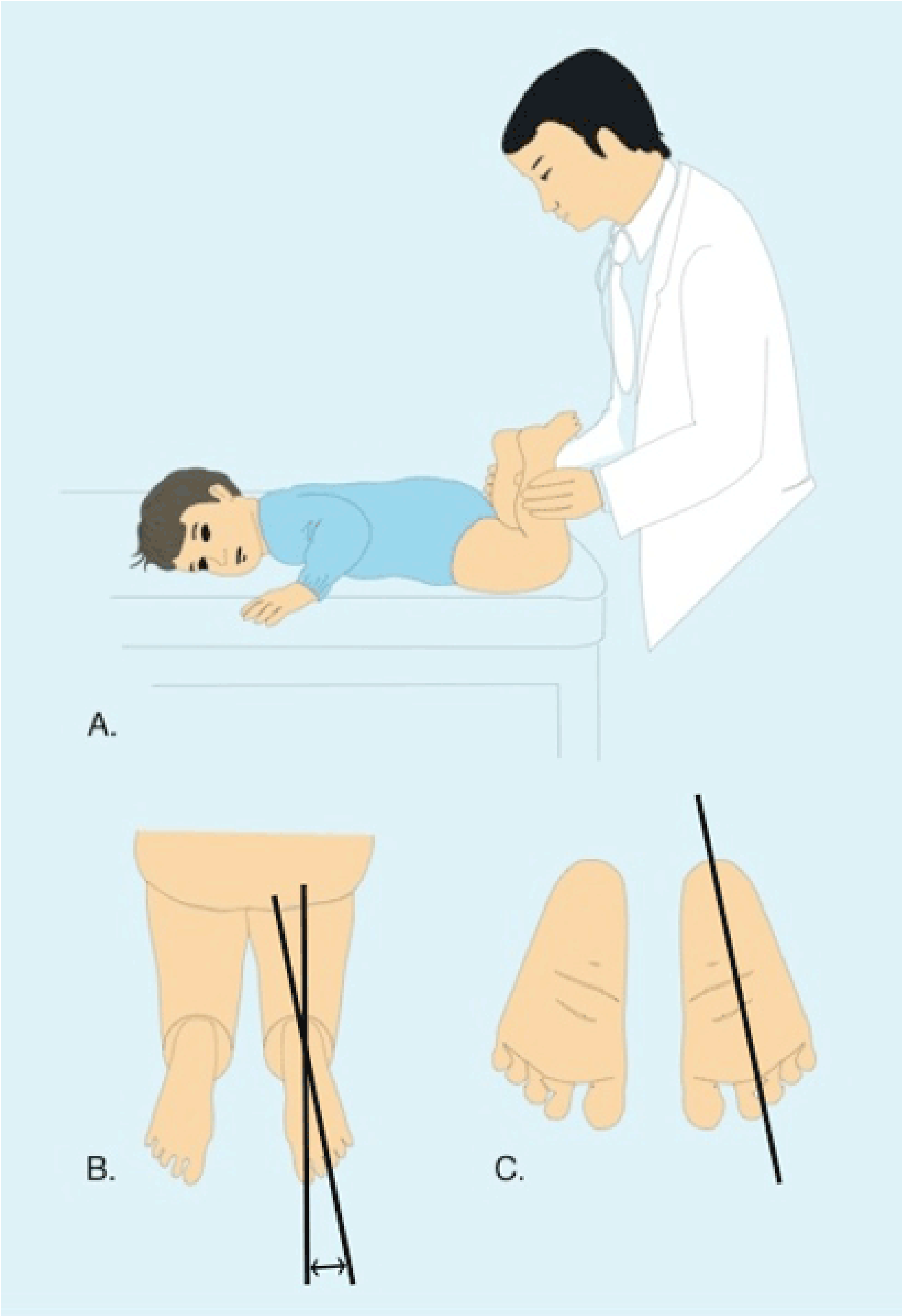
- Arc of hip rotation (hip internal and external rotation)



Internal and external rotation of hip in extension is assessed with patient prone and knee flexed 90°

From the collection of Tamir Bloom, MD

- Thigh-foot angle

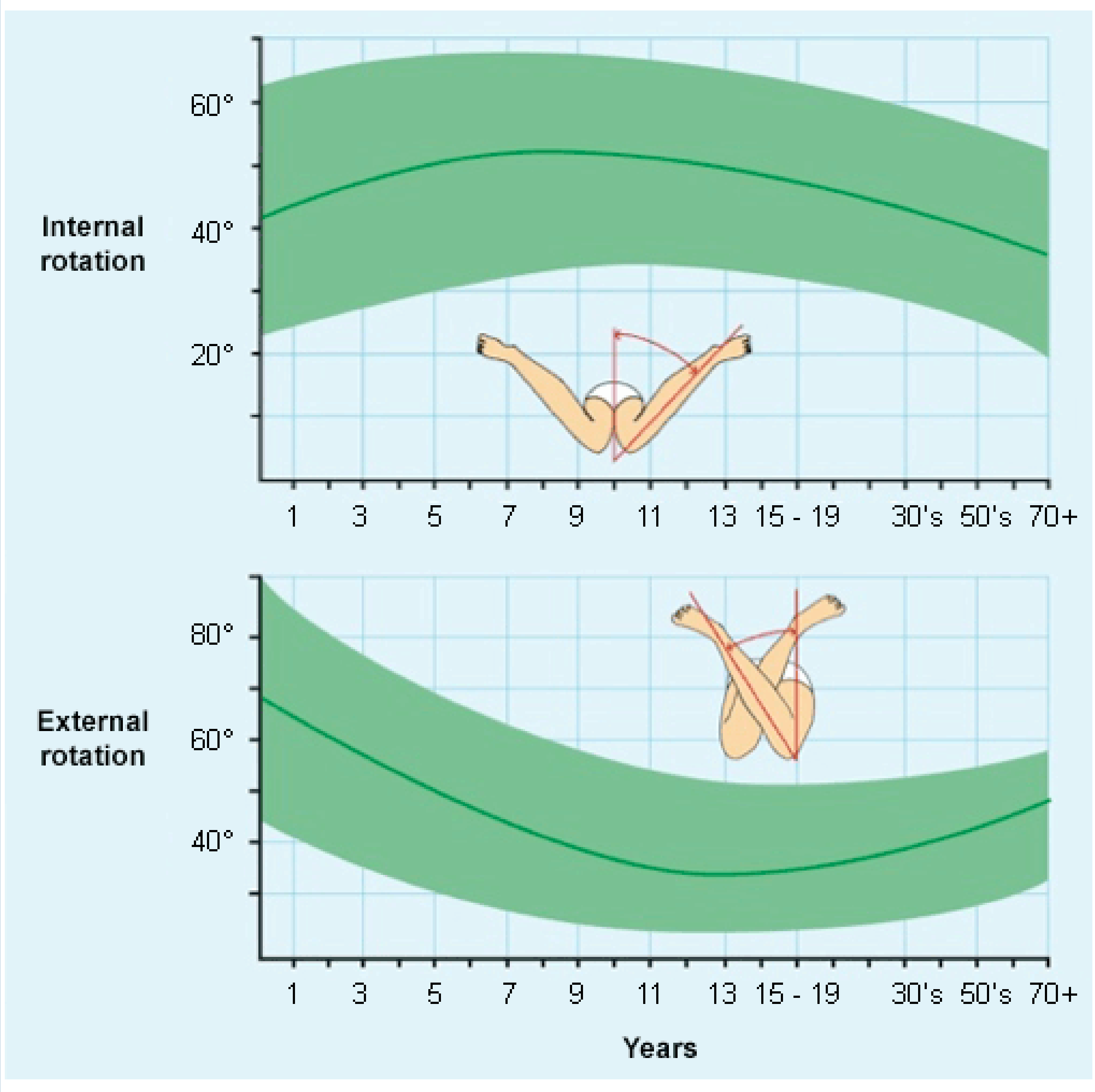


A,B: Thigh-foot axis assessed in prone position by measuring the angle between the longitudinal axis of the thigh and of the foot. C: Sole shape should be evaluated for forefoot adduction and abduction abnormalities such as metatarsus adductus. Heel-bisector line (drawn through midline axis of hindfoot and forefoot), in a normal foot, passes through the second web space. Lateral border of the foot is normally straight

From the collection of Lynn T. Staheli, MD

- Transmalleolar axis: assesses the amount of tibial torsion present; this axis is the angle formed at the intersection of an imaginary line from the lateral to the medial femoral condyles, and a second line from the lateral to the medial malleolus
- Heel-bisector line

Clinical values should be compared with published reference values to determine the relevance of findings based on physical exam.



Normal range and development of hip rotation throughout childhood. Green: normal ranges, mean ± 2 standard deviations

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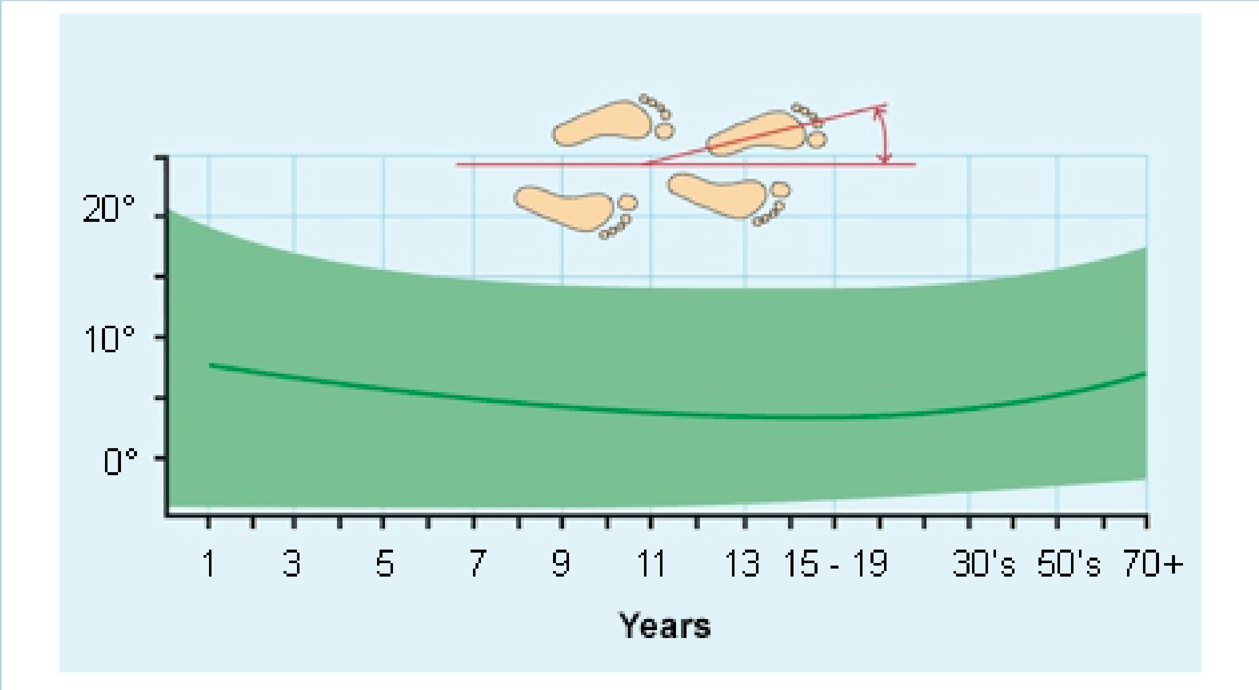

Normal range and development of foot progression angle throughout childhood. Green: normal ranges, mean ± 2 standard deviations

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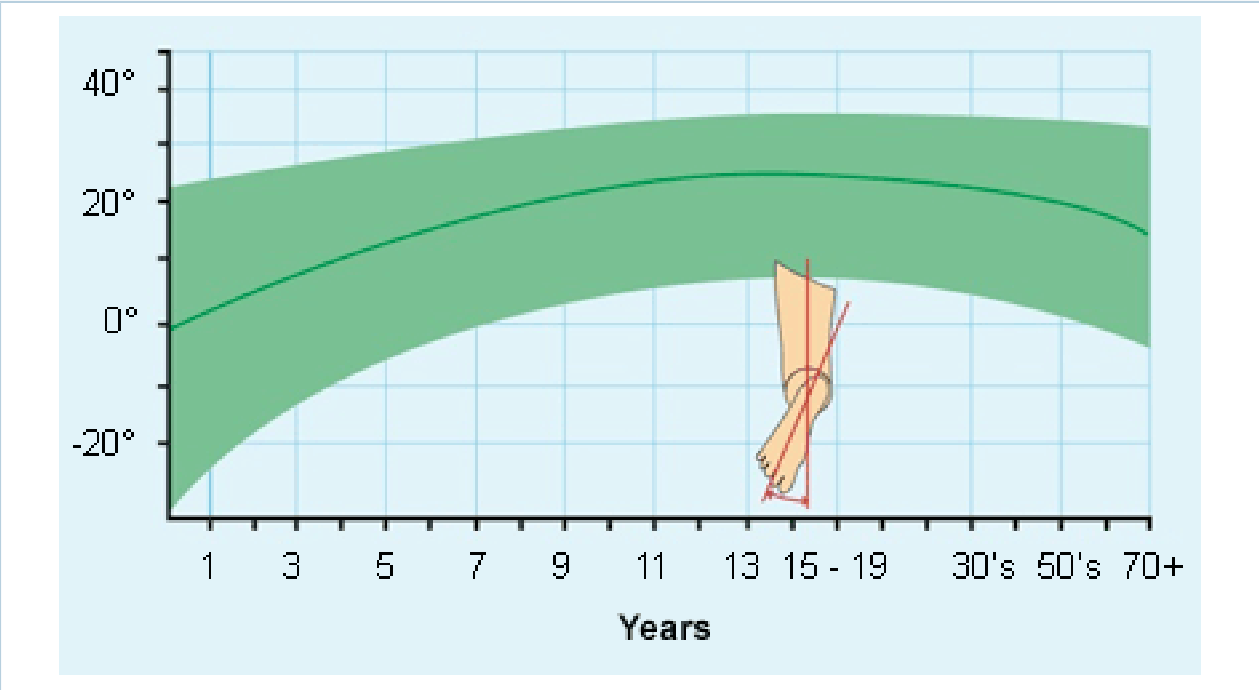


Normal range and development of thigh-foot angle throughout childhood. Green: normal ranges, mean ± 2 standard deviations

From the collection of Lynn T. Staheli, MD

The anatomic definition of tibial torsion is not precise, and the optimal technique for clinical assessment is debatable. Tibial torsion is best assessed by the thigh-foot angle, the transmalleolar axis (TMA), and the second-toe test.[1] [25] [49] The TMA may be more accurate than the thigh-foot angle and second-toe test in children with foot deformities.[50] Another technique for measuring tibial torsion is the footprint method.[51] With the patient sitting, the footprint is traced on precisely placed lined paper. A line is then drawn connecting the 2 malleoli. The angles between the malleoli and any line on the paper are used to determine the TMA.

Femoral anteversion is evaluated by comparing internal and external rotation of the hip in the prone position, as well as palpating the point of maximal trochanteric prominence.[52] [53] [54] Prone measurements of hip rotation are more accurate than supine measurements because the pelvis is stabilized.

Angular deformities commonly coexist with rotational abnormalities and should be assessed by measuring the intercondylar or transmalleolar distance. These measurements, including the rotational profile, can then be compared with published reference values.[2] [55]

Clinical exam in the office setting is limited, because it is primarily based on static evaluation of the lower extremity, whereas functional activities, such as walking, are dynamic.[56] In addition, torsional measurement may inaccurately assess deformity because of excessive joint laxity, joint contractures, and muscle spasticity, and when torsional deformities exist along with angular deformities.[2] [57] [58] [59]

Neuromuscular conditions are determined through neurologic exam, including testing of primitive reflexes, postural and protective reactions, and motor tone. Abnormal movement patterns help to identify a child with a potential neuromuscular condition. Many conditions have multiple orthopedic components; the exam should not focus on one body part.

Miserable malalignment syndrome may demonstrate a medially pointing patella ("squinting patella"). A W sitting position may be present and the Q angle (formed from a line drawn from the anterior superior iliac spine to the center of the kneecap, and from the center of the kneecap to the tibial tubercle) may be increased.

Photo of a child sitting in the W position

From the collection of Tamir Bloom, MD

In slipped capital femoral epiphysis, out-toeing or asymmetric hip range of motion in an adolescent is a possible sign.

A convex lateral border indicates forefoot adductus seen in metatarsus adductus with heel-bisector line hitting lateral to second web space and normal ankle range of motion. It is more frequently seen on the left and in the first year of life.

Flat feet may be seen in out-toeing. They are normally painless and not tender on exam. Assessing flexibility demonstrates an arch when the foot is raised or when the first metatarsophalangeal joint is passively dorsiflexed. The hindfoot inverts with ankle plantarflexion (standing on the balls of the feet).

In infantile Blount disease the cover-up test may be positive.[60] This qualitatively assesses the alignment of the proximal portion of the shank or lower leg relative to the thigh or upper leg. Neutral or varus alignment is considered a positive test.[60] Lateral knee thrust may be present in both adolescent and infantile Blount disease.

In skewfoot, the hindfoot is in valgus, the midfoot is abducted, and the forefoot is adducted.

In clubfoot, the equinus contracture with limited dorsiflexion of the ankle may be noted.

Radiographic evaluation

Radiographic evaluation is not needed during initial evaluation of most torsional problems. Radiographic techniques are generally not superior to clinical assessment.[52] Do not order radiographs for a child <8 years with simple in-toeing gait, which can be monitored unless there is severe tripping and falling, or asymmetry.[46] [61] In case of suspected hip pathology (e.g., slipped capital femoral, hip dysplasia) an anteroposterior pelvis and frog lateral views should be obtained. However, for a child <4 months old, radiographs are usually not appropriate when assessing for developmental dysplasia of the hip.[62] Cross-table lateral film should be ordered when a child >8 years has had a recent change in gait and knee or hip pain. Foot x-rays help in the diagnosis of clubfoot, skewfoot, congenital vertical talus, and hallux valgus.

With miserable malalignment syndrome, standard radiographic anteroposterior, lateral, and Merchant views are used to evaluate for patella alta, patellar subluxation or dislocation, and trochlea morphology.

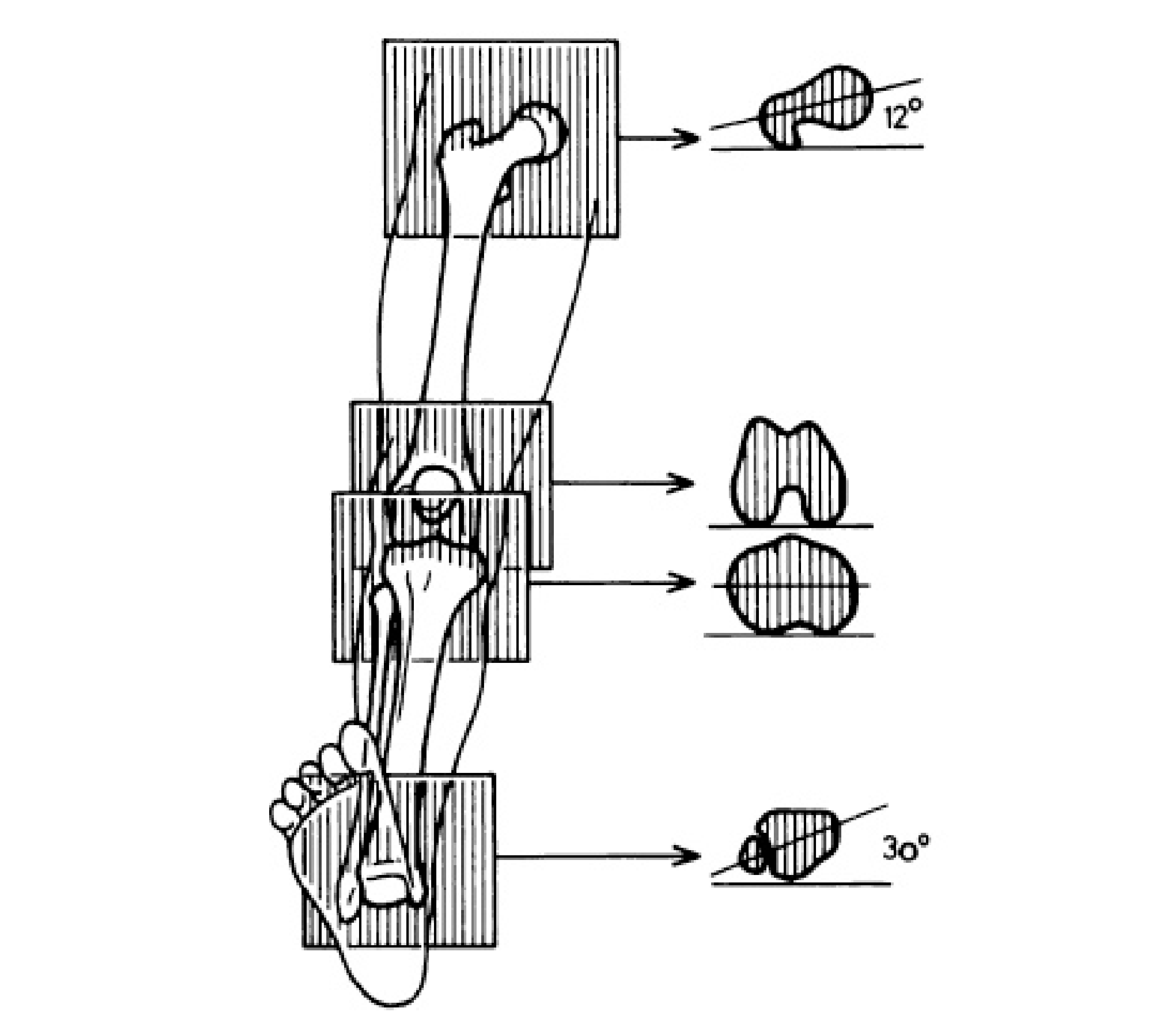
In Blount disease, the medial epiphyseal line may demonstrate irregularity and abnormal sloping of the medial tibial epiphysis. The metaphyseal portion of the plate may demonstrate irregular beaking.[63] [64] Imaging with standing anteroposterior x-ray of the lower extremities, including the hips and ankles, with the lower extremities rotated such that the knees (not the feet) are aligned straight ahead, is indicated in children >18 months of age with a positive cover-up test, asymmetric deformity, and family history of bowing or severe deformity.

With slipped capital femoral epiphysis, the epiphyseal plate is widened and the epiphysis appears somewhat shortened on the affected side and the margin of the metaphysis may appear indistinct on anteroposterior pelvis and lateral hip x-ray.

In skewfoot, standing anteroposterior and lateral x-rays of the foot confirm diagnosis. Z configuration of the foot on anteroposterior radiograph, with abduction of the midtarsal joints and adduction of the metatarsals, is seen. There is usually plantar flexion of the talus on the lateral x-ray.

Other investigations

Three-dimensional computed tomography (CT), magnetic resonance imaging (MRI), and ultrasound all accurately and precisely measure torsional alignment.[65] [66] [67] However, do not order CT or MRI in children until all appropriate clinical and plain radiographic exams have been completed.[61] CT ("gunsight" scan) evaluation of rotational profile may be used to measure severe or complex torsional deformities, such as miserable malalignment syndrome, in older children.[58] [68] [69] Concerns exist about excessive radiation exposure and measurement variability with plain radiographs and, even more so, with CT scan. If additional imaging is needed for preoperative evaluation, an MRI[70] [71] or EOS™[72] [73] [74]low-dose biplanar x-ray may be preferable to CT scan. The availability, cost, and need for sedation (with MRI) should be considered when contemplating advanced imaging for torsional abnormalities in children.



Severe torsional deformities may be assessed with gunsight CT scan by measuring the angle between the transverse axes on CT cuts of the proximal and distal juxta-articular regions

Quantitative gait analysis may provide information on dynamic alignment and range of motion. It is reserved for assessing gait abnormalities in neuromuscular conditions for surgical decision-making.

History and exam

Key diagnostic factors

convex lateral border of the sole of the foot (common)

- Lateral border with the patient prone is normally straight. Convex lateral border indicates forefoot adductus.

asymmetric hip range of motion (common)

- Increased external rotation and decreased internal rotation compared with the other side may indicate slipped capital femoral epiphysis.

Other diagnostic factors

foot progression angle >2 standard deviations outside the mean for age (uncommon)

- Positive values indicate out-toeing. Negative values indicate intoeing. Infant: <-20°. By age 8 years, >30° or <-20° indicates significant deformity.[2]

hip medial rotation >2 standard deviations outside the mean for age (uncommon)

- In an infant >60° and adolescent >70° indicate increased femoral anteversion.[2]

hip lateral rotation >2 standard deviations outside the mean for age (uncommon)

- In an adolescent >70° indicates increased femoral retroversion.[2]

thigh-foot axis >2 standard deviations outside the mean for age (uncommon)

- Average in infants is 5° internal (range -30° to +20°). By age 8 years, >30° indicates lateral tibial torsion, and <-10° indicates medial tibial torsion.[2]

transmalleolar axis >2 standard deviations outside the mean for age (uncommon)

- Averages about -4° in newborns. By age 7 to 8 years >40° indicates lateral tibial torsion.[2]

heel-bisector line (uncommon)

- A line projecting lateral to the second web space suggests forefoot adduction. A line passing more medially suggests forefoot abduction.

sitting in the W position (uncommon)

- Children with medial femoral torsion tend to sit with the legs medially rotated because lateral rotation of the hips is limited and may be uncomfortable.

medial-facing patella (squinting or cross-eyed patella) (uncommon)

- Seen in children with medial femoral anteversion during stance and gait.

lateral knee thrust (uncommon)

- Knee abruptly translates laterally as weight is placed on the leg during stance phase of gait.

Risk factors

Strong

neuromuscular disease

- Developmental torsional deformities are common in children with cerebral palsy, myelomeningocele, and polio.[13] [45]

intrauterine position abnormalities

- Abnormal shaping of structures caused by mechanical forces leading to torsional deformities.

Weak

family history#of rotational problems

- Mothers of patients with medial femoral torsion often recall a history of femoral torsion when they were children, and have a similar or less pronounced rotational profile pattern as adults.[1]

female sex

- Regardless of age, females have greater hip medial rotation and a greater total arc of hip range of motion than males, which may predispose them to intoeing.[22] [24]

short stature or disproportionate body-limb ratio

- May be associated in cases of skeletal dysplasia.
- [Nemours Foundation: skeletal dysplasia] (http://www.nemours.org/content/nemours/wwwv2/service/medical/skeletaldysplasia.html)

ligamentous laxity

- Associated with torsional deformities by increasing intra-articular joint motion. Patient is asked to touch the thumb to the volar surface of the forearm, hyperextend the little finger metacarpophalangeal joint >90°, hyperextend the elbows, hyperextend the knees, and place the palms of the hands on the floor with forward bending.

Tests

1st test to order

Test	Result
anteroposterior pelvic x-rays • Ordered when hip exam is marked by pain or asymmetric range of motion, neuromuscular diseases, or gait abnormality that is not easily explained by rotational profile. • Rules out hip dysplasia, slipped capital femoral epiphysis, avascular necrosis of the femoral head, and hip osteoarthrosis. • However, do not order radiographs for a child <4 months with suspected hip dysplasia or for a child <8 years with simple in-toeing gait, which can be monitored unless there is severe tripping and falling, or asymmetry.[46] [61] [62]	**normal for most torsional deformities**
cross-table lateral x-ray of knee and hip • Ordered in a child >8 years of age with a recent change or abnormality in gait, and knee or hip pain. • Rules out hip dysplasia, slipped capital femoral epiphysis, avascular necrosis of the femoral head, hip osteoarthrosis, or Blount disease. • However, do not order radiographs for a child <8 years with simple in-toeing gait, which can be monitored unless there is severe tripping and falling, or asymmetry.[46] [61]	**normal for most torsional deformities**
foot x-rays • Taken in the weight-bearing position. • Helps diagnose clubfoot, skewfoot, congenital vertical talus, and hallux valgus. • Order if any foot deformities are noted on examination or if the feet are painful, swollen, or stiff. • However, do not order radiographs for a child <8 years with simple in-toeing gait, which can be monitored unless there is severe tripping and falling, or asymmetry.[46] [61]	**normal for most torsional deformities; positive for other causes of intoeing, such as hallux varus, metatarsus adductus, and clubfoot**

Other tests to consider

Test	Result
3-dimensional imaging • Three-dimensional CT, MRI, EOS™, and ultrasound all accurately and precisely measure torsional alignment.[65] [66] [67] Primarily reserved for surgical planning and rarely indicated for routine evaluation.[75] • Do not order CT or MRI in children until all appropriate clinical and plain radiographic exams have been completed.[61]	**helps to quantify the location and magnitude of each torsional deformity**
CT rotational profile evaluations • May be used to measure severe or complex torsional deformities, such as miserable malalignment syndrome, in older children. • Do not order CT in children until all appropriate clinical and plain radiographic exams have been completed.[61]	**helps to quantify the location and magnitude of each torsional deformity**

Emerging tests

Test	Result
quantitative gait analysis • Provides information on dynamic alignment and range of motion. Primarily reserved for assessing gait abnormalities in neuromuscular conditions (e.g., cerebral palsy) for surgical decision-making.	**helps to quantify the location and magnitude of each torsional deformity**

Differentials

Condition	Differentiating signs / symptoms	Differentiating tests
Metatarsus primus varus	• Isolated adducted first metatarsal. • Normal alignment of lateral border of foot. • Vertical skin crease at the tarsometatarsal joint on the medial side of the foot.	• Foot x-rays. Angulation of the first metatarsal bone toward the midline of the body.
Positional calcaneovalgus	• Identified at birth. • Ankle dorsiflexed with mild subtalar joint eversion. • Ankle dorsiflexion is flexible.	• Clinical diagnosis. Routine imaging studies not necessary.
Hip dysplasia	• Hip abduction and symmetry should be assessed to rule out hip dysplasia.	• Anteroposterior pelvic x-ray may demonstrate dysplasia of the hip.
Congenital femoral deficiency	• A spectrum of congenital isolated limb deficiency with a short femur in an otherwise normal child. • The affected thigh is shorter than the contralateral thigh, and the leg may be shorter.	• Anteroposterior pelvic x-ray and anteroposterior x-ray of the lower extremities. • Femoral deficiency ranges from mild shortening to total absence of the proximal femur, and apparent discontinuity between the femoral neck and shaft. Typified by valgus and external rotation deformity of the knee, hip abduction and flexion contracture associated with fibular hemimelia, and absence of the cruciate ligaments of the knee.

DIAGNOSIS

Approach

Treatment approach is based on correct diagnosis, understanding the natural history of the condition, and the effectiveness of various treatment options. Managing family concerns is usually the major challenge and can be addressed by providing the correct diagnosis, education, reassurance, and follow-up for worried parents, and by resisting doing something to the child to satisfy the parents. While lower-limb position and appearance of gait may be a concern to many parents and families, orthopedic intervention should be based on long-term goals such as avoiding joint degeneration and pain, and preventing a decline in walking ability in children with neuromuscular diseases. Deformities that result in functional deficits during gait (i.e., not well compensated) are addressed with corrective surgery designed to restore normal anatomic alignment.[25]

Healthy (no comorbidities) patients with intoeing or out-toeing and rotational profile 2 standard deviations within the mean for their age

Treatment of torsional problems in these children is both unnecessary and ineffective.[1] [2]

Initial treatment is reassurance and convincing the family that observation is best and that the condition may resolve over several months or years. Infants and toddlers with medial tibial torsion (MTT) should avoid sleeping prone and sitting on their feet. Toddlers and children with increased femoral anteversion should sit cross-legged and avoid sitting in the W position. Nonsurgical interventions, such as twister cables, night splints, shoe wedges, physical therapy, or a combination of these, are ineffective at altering limb alignment or normalizing gait.[1] [3] [76]

Referral to an orthopedist should be considered for the following: 1) families who require additional reassurance; 2) an uncertain diagnosis or inconclusive screening exam; 3) children with stiff forefoot adductus; and 4) older children or adolescents with leg pain or disability.

Healthy (no comorbidities) patients with intoeing or out-toeing with rotational profile 2 standard deviations beyond the mean for their age

Intoeing due to MTT: about 1% of children with intoeing will have persistent MTT into late childhood or adolescence severe enough to cause dissatisfaction with appearance of gait or function.[1] [26] [28] [68] [76] [77] Treatment with night splints is advocated by some (although with limited supporting evidence) but may be burdensome to the family and the child. Treatment with gait plates (a stiff orthotic inserted inside the shoe) is also advocated by some, as they may reduce the rate of tripping and alleviate parental concern as to the aesthetics of the child's intoeing gait.[78] [79] However, further research is needed to demonstrate the benefits of this treatment prior to widespread application to clinical practice.[80] Operative correction is indicated in selected children older than 8 years with significant deformity that disrupts gait function,[26] [28] and with a thigh-foot angle >3 standard deviations (SDs) beyond the mean.[81] Femoral alignment must be considered before surgical treatment, as femoral rotation can aggravate or compensate for tibial torsion.

Out-toeing due to lateral tibial torsion (LTT): this is generally more problematic than MTT and more likely to require operative correction. Operative correction is indicated in children older than 8 years, with significant functional deformity, and with a thigh-foot angle >40° or 3 SDs beyond the mean.[81]

Medial femoral torsion (MFT) (increased femoral anteversion): in rare cases (<1%), MFT may persist and be severe enough to cause disability in late childhood or adolescence. Operative treatment is never indicated prophylactically. Surgical correction, consisting of a rotational femoral osteotomy (usually performed at the proximal femur), may be indicated in older children with severe deformities>3 SDs beyond the mean, medial hip rotation of 80° to 90° or lateral rotation of 0°, external rotation 20° or less, and significant functional disability.[81]

Torsional malalignment syndrome

Excessive LTT and MFT associated with anterior knee symptoms, including patellofemoral pain, patella subluxation, or, rarely, dislocation, are initially treated conservatively.

Torsional malalignment syndrome in children with cerebral palsy

Torsional deformity is just one factor that contributes to pathologic gait in patients with cerebral palsy.[82] Muscle imbalance, spasticity, and contractures may require tone-reducing medications (e.g., onabotulinumtoxinA) [83] [84]or soft-tissue procedures (e.g., tenotomy, tendon transfer, and muscle release) before bony procedures.[11] [85] Some patients may benefit from derotation osteotomies to improve limb alignment and gait.[86] Although gait analysis may aid in decision making, indications for operative intervention are less clear in the literature in this population.[45] [76]

Metatarsus adductus

Most metatarsus adductus deformities correct spontaneously with little if any long-term disability even with mild to moderate residual deformity.[87] [88] A flexible foot (the forefoot can be passively abducted so that the heel-bisector line is beyond the second web space) can be observed. A flexible foot that corrects to midline may be treated with a home stretching program.[89] A foot that does not correct to midline or does not improve with stretching may be serially casted every 1 to 2 weeks. Casting results are best when initiated before 8 months of age. Surgery is occasionally considered in children >4 years old for feet with severe deformity.

Clubfeet

Patients should be referred to an orthopedist for treatment.

Flat feet (pes planovalgus)

Flexible, painless, flat feet are typically not pathologic and do not predispose a child to foot pain as an adult. Flexible, asymptomatic flat feet do not require intervention and there is no evidence that corrective shoes or inserts are effective for painless flat feet.[46] [89] In symptomatic children, initial treatment is reassurance and shoes with a well-formed arch support in older children. A custom orthotic may be prescribed if pain persists despite the use of an off-the-shelf orthotic. Flexible flat feet associated with hindfoot pain resulting from a contracted gastrocnemius-soleus may be treated with Achilles tendon stretching exercises. Painful and stiff flat feet require referral to an orthopedist.

Blount disease

In infantile Blount disease, the deformity is restricted to the proximal tibia (no femoral involvement). Before age 18 months differentiation between physiologic bowing and Blount disease is difficult. In this group, routine radiographic screening and referral are not cost-effective and expose children to unnecessary radiation. For children <3 years old, observation every 3 to 6 months is recommended. Bracing (with a medial upright knee-ankle-foot orthosis) has limited effectiveness in certain patients in the early stages of the disease. Surgical correction is required for brace failure or for severe deformity before age 4 years.

Adolescent Blount disease requires referral to an orthopedist for treatment. Surgery to restore the normal anatomic alignment is the mainstay of treatment.

Treatment algorithm overview

Please note that formulations/routes and doses may differ between drug names and brands, drug formularies, or locations. Treatment recommendations are specific to patient groups: see disclaimer

Ongoing (summary)

no comorbidity		
rotational profile within 2 standard deviations of the mean for age: intoeing or out-toeing	1st	reassurance
	adjunct	orthopedist referral
rotational profile beyond 2 standard deviations of the mean for age: intoeing	1st	night splints
	2nd	gait plates
	adjunct	surgical correction
rotational profile beyond 2 standard deviations of the mean for age: out-toeing	1st	surgical correction
specific comorbidity		
torsional malalignment: without cerebral palsy	1st	conservative management
torsional malalignment: with cerebral palsy	1st	surgery or botulinum toxin
metatarsus adductus	1st	stretching and serial casting
	adjunct	surgery
clubfeet	1st	orthopedic referral
flat feet: without pain	1st	reassurance
flat feet: with pain	1st	supportive care
	adjunct	orthopedic referral
infantile Blount disease	1st	observation
	adjunct	bracing
	adjunct	surgery
adolescent Blount disease	1st	orthopedic referral

Treatment algorithm

Please note that formulations/routes and doses may differ between drug names and brands, drug formularies, or locations. Treatment recommendations are specific to patient groups: see disclaimer

Ongoing

no comorbidity

■ rotational profile within 2 standard deviations of the mean for age: intoeing or out-toeing

1st **reassurance**

» Treatment of torsional problems in healthy children is both unnecessary and ineffective.[1] [2]

» Infants and toddlers with medial tibial torsion should avoid sleeping prone and sitting on their feet. Toddlers and children with increased femoral anteversion should sit cross-legged and avoid sitting in the W position. Twister cables, night splints, shoe wedges, physical therapy, or a combination of these is ineffective at altering limb alignment or normalizing gait.[1] [3] [76]

adjunct **orthopedist referral**

Treatment recommended for SOME patients in selected patient group

» Referral to an orthopedist should be considered for: 1) families who require additional reassurance; 2) uncertain diagnosis or inconclusive screening exam; 3) children with stiff forefoot adductus; and 4) older children or adolescents with leg pain or disability.

■ rotational profile beyond 2 standard deviations of the mean for age: intoeing

1st **night splints**

» About 1% of children with intoeing will have persistent medial tibial torsion into late childhood or adolescence severe enough to cause dissatisfaction with appearance of gait or function.[1] [68] [76] [77] Treatment with night splints is advocated by some (although with limited supporting evidence) but may be burdensome to the family and the child.

2nd **gait plates**

» Treatment with gait plates (a stiff orthotic inserted inside the shoe) is advocated by some and may reduce the rate of tripping and alleviate parental concern as to the aesthetics of the child's intoeing gait (although with weak supporting evidence).[79] [78] Further research is needed to demonstrate the benefits of this treatment prior to widespread application to clinical practice.[80]

adjunct **surgical correction**

Ongoing

		Treatment recommended for SOME patients in selected patient group » Indicated in selected children ages >8 years with significant deformity that disrupts gait function,[26] [28] and with thigh-foot angle >3 standard deviations beyond the mean.[81] Femoral alignment must be considered before surgical treatment, as femoral rotation can aggravate or compensate for tibial torsion. » In rare cases (<1%) medial femoral torsion may persist and be severe enough to cause disability in late childhood or adolescence. Surgical treatment is never indicated prophylactically. Surgical correction, consisting of a rotational femoral osteotomy (usually performed at the proximal femur), may be indicated in older children with severe deformities >3 standard deviations beyond the mean, medial hip rotation 80° to 90° or lateral rotation 0°, external rotation ≤20°, and significant functional disability.[81]
■ **rotational profile beyond 2 standard deviations of the mean for age: out-toeing**	**1st**	**surgical correction** » Out-toeing due to lateral tibial torsion is generally more problematic than medial tibial torsion and more likely to require operative correction. Indicated in selected children ages >8 years, with significant functional deformity, and with thigh-foot angle >40° or 3 standard deviations beyond the mean.[81]

specific comorbidity

■ **torsional malalignment: without cerebral palsy**	**1st**	**conservative management** » Excessive lateral tibial torsion and medial femoral torsion associated with anterior knee symptoms, including patellofemoral pain, patella subluxation, or, rarely, dislocation, are initially treated conservatively.
■ **torsional malalignment: with cerebral palsy**	**1st**	**surgery or botulinum toxin** **Primary options** » onabotulinumtoxinA: consult specialist for guidance on dose » Torsional deformity is just 1 factor that contributes to pathologic gait in patients with cerebral palsy.[82] Muscle imbalance, spasticity, and contractures may require tone-reducing medications (e.g., onabotulinumtoxinA)[83] [84]or soft-tissue procedures (e.g., tenotomy, tendon transfer, and muscle release) before bony procedures.[11] [85] Some patients may

Ongoing

		benefit from derotation osteotomies to improve limb alignment and gait.[86] Although gait analysis may aid decision making, indications for operative intervention are less clear in the literature in this population.[45] [76]
metatarsus adductus	1st	**stretching and serial casting** » A flexible foot (the forefoot can be passively abducted so that heel-bisector line is beyond second web space) can be observed. A flexible foot that corrects to midline may be treated with a home stretching program.[89] A foot that does not correct to midline or does not improve with stretching may be serially casted every 1 to 2 weeks. Casting results are best when initiated before age 8 months.
	adjunct	**surgery** Treatment recommended for SOME patients in selected patient group » Surgery is occasionally considered in children >4 years old for feet with severe deformity.
clubfeet	1st	**orthopedic referral** » Require referral to an orthopedist for treatment.
flat feet: without pain	1st	**reassurance** » Flexible, painless, flat feet are typically not pathologic and do not predispose a child to foot pain as an adult. Flexible, asymptomatic flat feet do not require intervention and there is no evidence that corrective shoes or inserts are effective for painless flat feet.[46] [89]
flat feet: with pain	1st	**supportive care** » Initial treatment is reassurance and shoes with well-formed arch support in older children. A custom orthotic may be prescribed if pain persists despite the use of an off-the-shelf orthotic. Flexible flat feet associated with hindfoot pain resulting from a contracted gastrocnemius-soleus may be treated with Achilles tendon stretching exercises.
	adjunct	**orthopedic referral** Treatment recommended for SOME patients in selected patient group » Painful and stiff flat feet require referral to an orthopedist.
infantile Blount disease	1st	**observation** » For children <3 years old, observation every 3 to 6 months is recommended.

Ongoing

	adjunct	**bracing** Treatment recommended for SOME patients in selected patient group » Bracing (with a medial upright knee-ankle-foot orthosis) has limited effectiveness in certain patients in the early stages of the disease.
	adjunct	**surgery** Treatment recommended for SOME patients in selected patient group » Surgical correction is required for brace failure or for severe deformity before age 4 years.
■ **adolescent Blount disease**	**1st**	**orthopedic referral** » Surgery to restore the normal anatomic alignment is the mainstay of treatment.

Patient discussions

In most cases, torsional deformities in healthy children are minor and self-limiting. Parental education, reassurance, a handout, and an offer to see the child again are all recommended.

If there is no underlying disorder or condition (e.g., slipped capital femoral epiphysis, cerebral palsy, hip dysplasia, etc), no treatment, other than observation, may be offered. Unnecessary treatment for intoeing and out-toeing may be harmful. Operative treatment may be appropriate for fewer than 1% of patients in cases where the condition is severe, and may cause disability.

Parents may rationalize frequently tripping and falling in their children on the basis of intoeing or flat feet; however, there is no evidence to support this perception. Tripping is common in toddlers because they do not automatically lift their toes up.

Suspected deviations in growth and development should be brought to the attention of a pediatrician.

[Pediatric Orthopaedic Society of North America] (https://posna.org/Patient-Education/OrthoInfo)

Monitoring

Monitoring

In general, follow-up visits are not recommended, provided the diagnosis is correct, as the natural history suggests spontaneous resolution. Follow-up may be recommended to address parental concerns or if deformities persist and produce functional disability in late childhood (incidence is 1/1000).

Complications

Complications	Timeframe	Likelihood
surgery-related complications	**variable**	**low**
Most complications of intoeing and out-toeing are related to their surgical treatment.[75] Potential surgical-related complications include residual deformity (resulting from undercorrection, overcorrection, loss of correction, or failure to address associated deformities), recurrence of deformity with continued skeletal growth, pseudarthrosis, growth disturbance, and nerve injury.		

Prognosis

Healthy (no comorbidity) patients with intoeing or out-toeing and rotational profile 2 standard deviations within the mean for their age

Despite the wide variation of rotational profiles in infants and toddlers, the natural history is gradual normalization by age 5 to 6 years. The vast majority of torsional variations correct with growth because version, soft-tissue pliability, and muscle coordination change as walking commences and matures.

Torsional variations do not cause long-term problems to other joints and the spine. There is no evidence suggesting that either medially or laterally rotated limbs increase the risk of falling or impair function.[90] Intoeing while running tends to be more common in sprinters, allowing the toe flexors to more effectively enhance push-off.[91]

Tibial torsion: the normal tibia is laterally rotated 5° at birth and increases to 15° to 20° at skeletal maturity.[92] Medial tibial torsion (MTT) usually corrects 1 to 2 years after physiologic bowing resolves. Lateral tibial torsion (LTT) is less common in infancy than MTT but is more likely to persist in later childhood. This may decrease walking agility and speed if severe. LTT does not usually resolve with growth.[81]

Most newborns have external rotation contractures of the hips thought to be due to intrauterine positioning. This usually resolves during early walking, at which time intoeing may be noticed, commonly due to MTT. Femoral torsion: femoral anteversion (medial rotation) decreases from about 40° (range, 15° to 50°) to 20° (range, 10° to 35°) by age 10 years.[1] [2] [3] [4] [93] [94] There is limited evidence linking anteversion in adults with physical performance or hip osteoarthritis.[31] [95] [96] [97] [98] Medial femoral torsion (MFT) does not cause foot deformities, and foot deformities do not cause MFT.

Healthy (no comorbidity) patients with intoeing or out-toeing with rotational profile 2 standard deviations beyond the mean for their age

Most torsional deformities resolve with normal growth and development. A growing body of evidence suggests that residual lower-limb rotational malalignment may be associated with premature osteoarthrosis of the hip, knee, and ankle joints.[41] [29] [30] [31] [42] [99] Excessive LTT has been associated with progressive equinoplanovalgus foot malalignment, hallux valgus malalignment, and osteochondritis dissecans of the knee.[3] [100] [101] [102]

Torsional malalignment syndrome without cerebral palsy

The natural history is one of progression of symptoms, rarely resolution.[68] [103]

Torsional malalignment in children with cerebral palsy

The natural history is one of progression of symptoms, rarely resolution.[104] [105] [106]

Treatment guidelines

International

Footwear for children (https://www.cps.ca/en/documents) [89]

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Online resources

1. Nemours Foundation: skeletal dysplasia (http://www.nemours.org/content/nemours/wwwv2/service/medical/skeletaldysplasia.html) *(external link)*

2. Pediatric Orthopaedic Society of North America (https://posna.org/Patient-Education/OrthoInfo) *(external link)*

ONLINE RESOURCES

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Images

Figure 1: Photo of a child sitting in the W position

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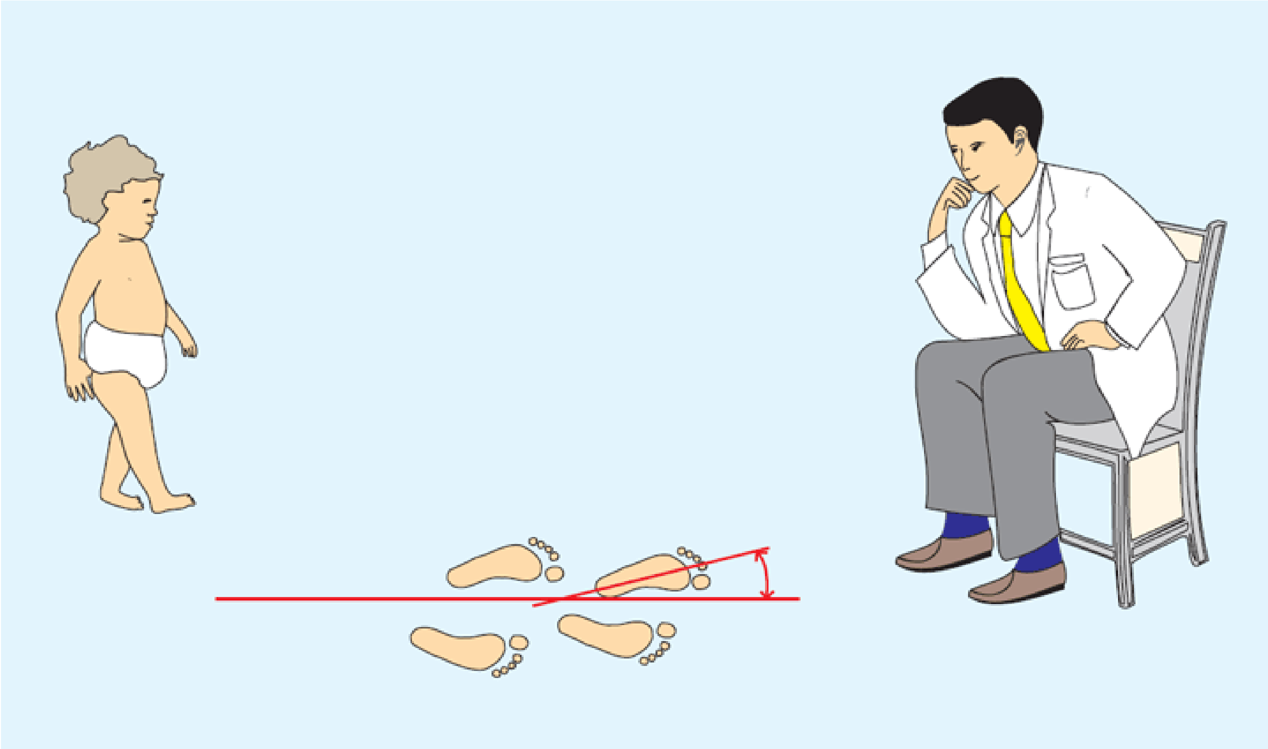

Figure 2: Foot progression angle (FPA) assessed while watching the child walk. FPA is formed by a line drawn in direction of walking and a line from the longitudinal axis of the foot. FPA is summation of torsional alignments of femur, tibia, and foot. Intoeing is designated as a negative number and out-toeing a positive number

From the collection of Lynn T. Staheli, MD

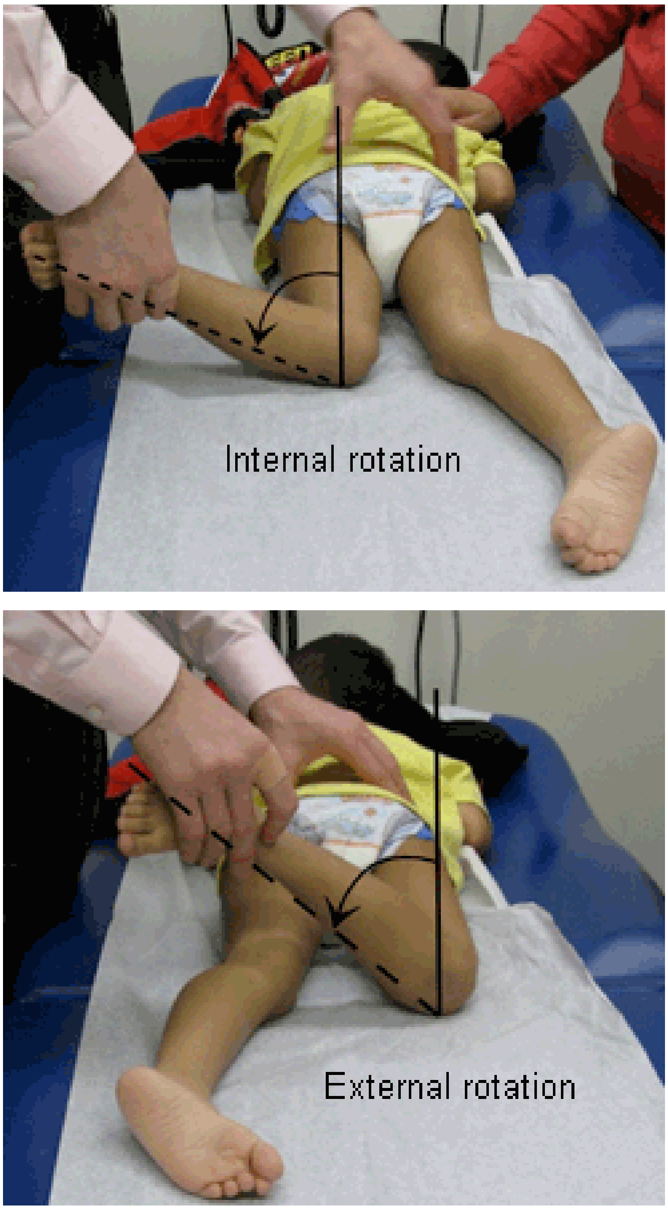

Figure 3: Internal and external rotation of hip in extension is assessed with patient prone and knee flexed 90°

From the collection of Tamir Bloom, MD

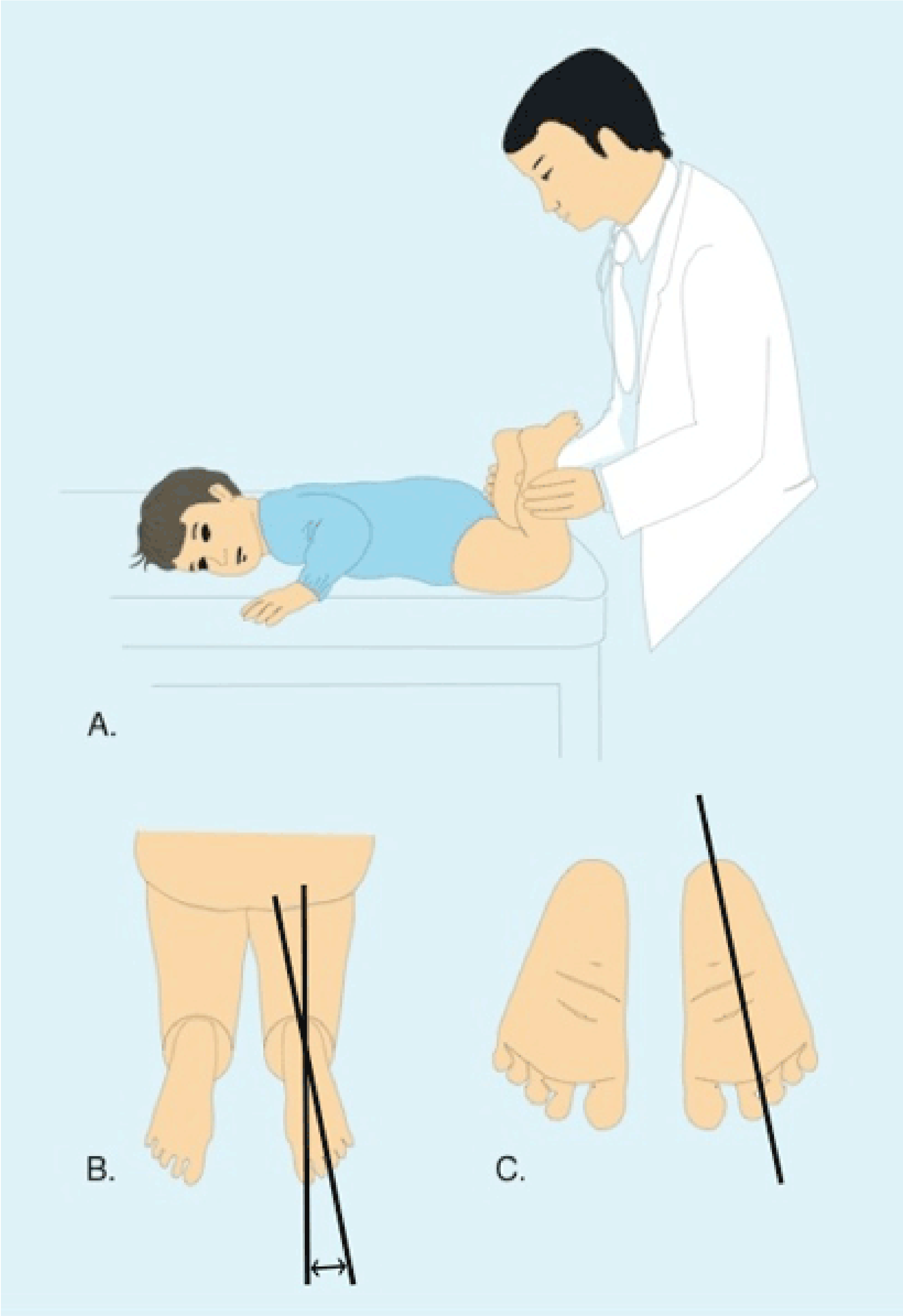

Figure 4: A,B: Thigh-foot axis assessed in prone position by measuring the angle between the longitudinal axis of the thigh and of the foot. C: Sole shape should be evaluated for forefoot adduction and abduction abnormalities such as metatarsus adductus. Heel-bisector line (drawn through midline axis of hindfoot and forefoot), in a normal foot, passes through the second web space. Lateral border of the foot is normally straight

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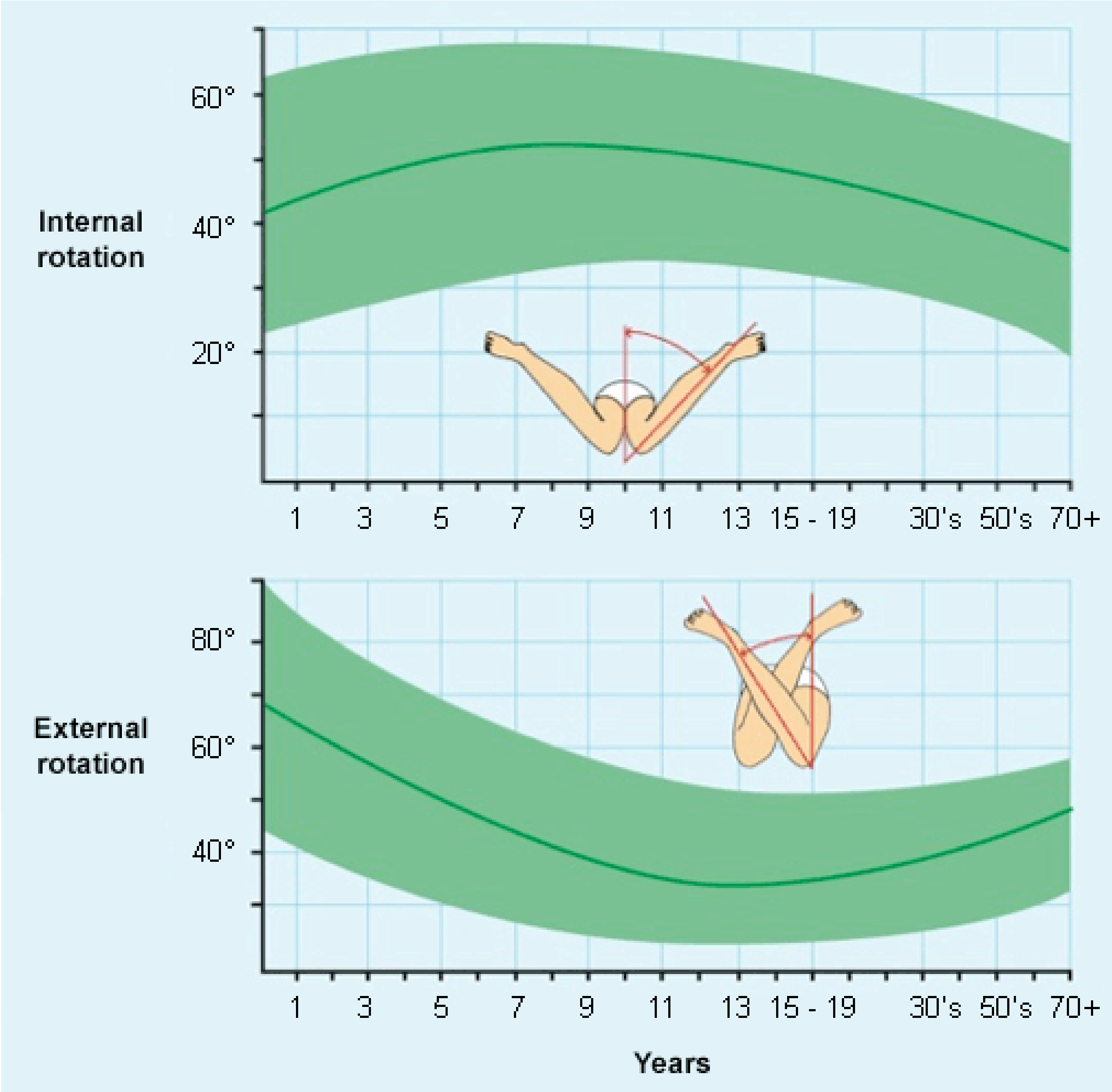

Figure 5: Normal range and development of hip rotation throughout childhood. Green: normal ranges, mean ± 2 standard deviations

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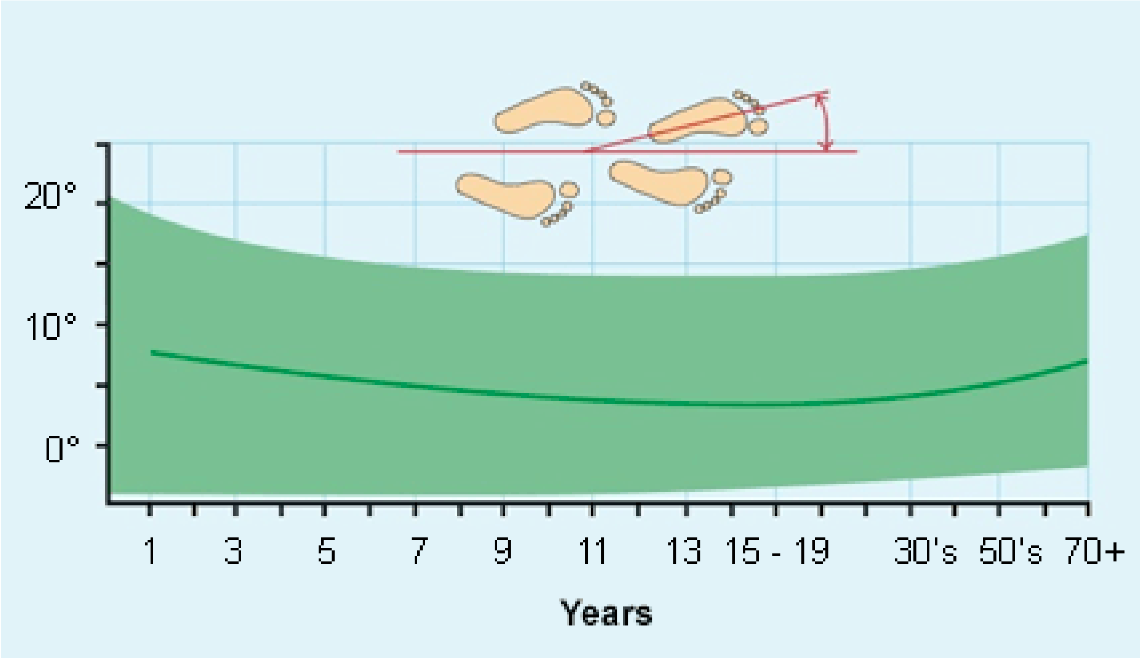

Figure 6: Normal range and development of foot progression angle throughout childhood. Green: normal ranges, mean ± 2 standard deviations

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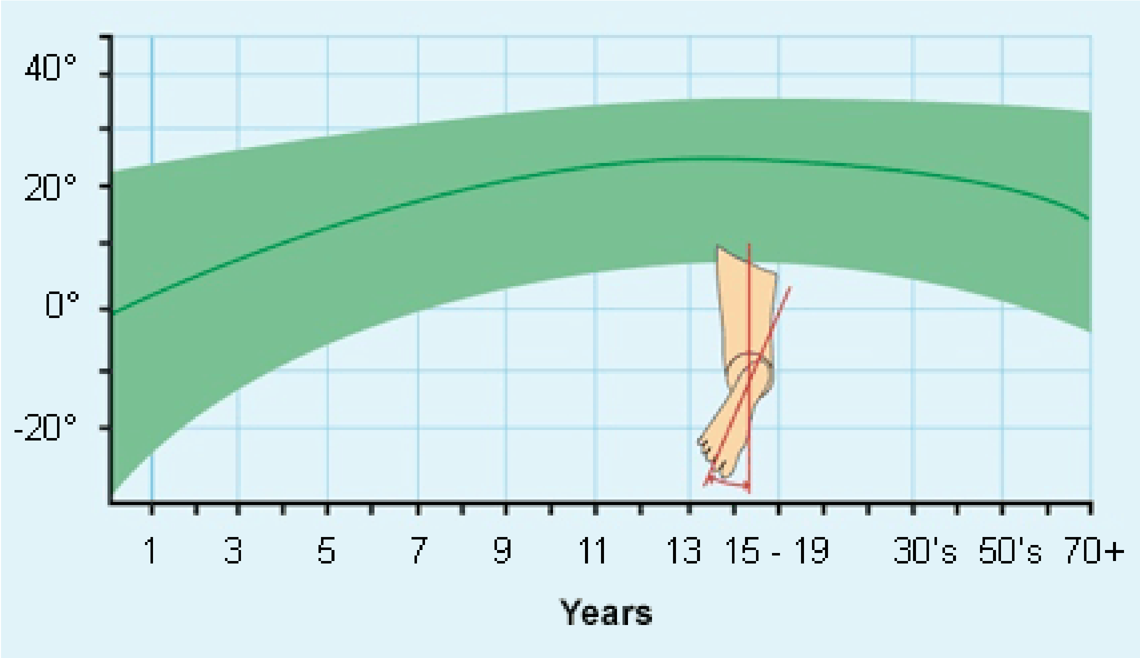

Figure 7: Normal range and development of thigh-foot angle throughout childhood. Green: normal ranges, mean ± 2 standard deviations

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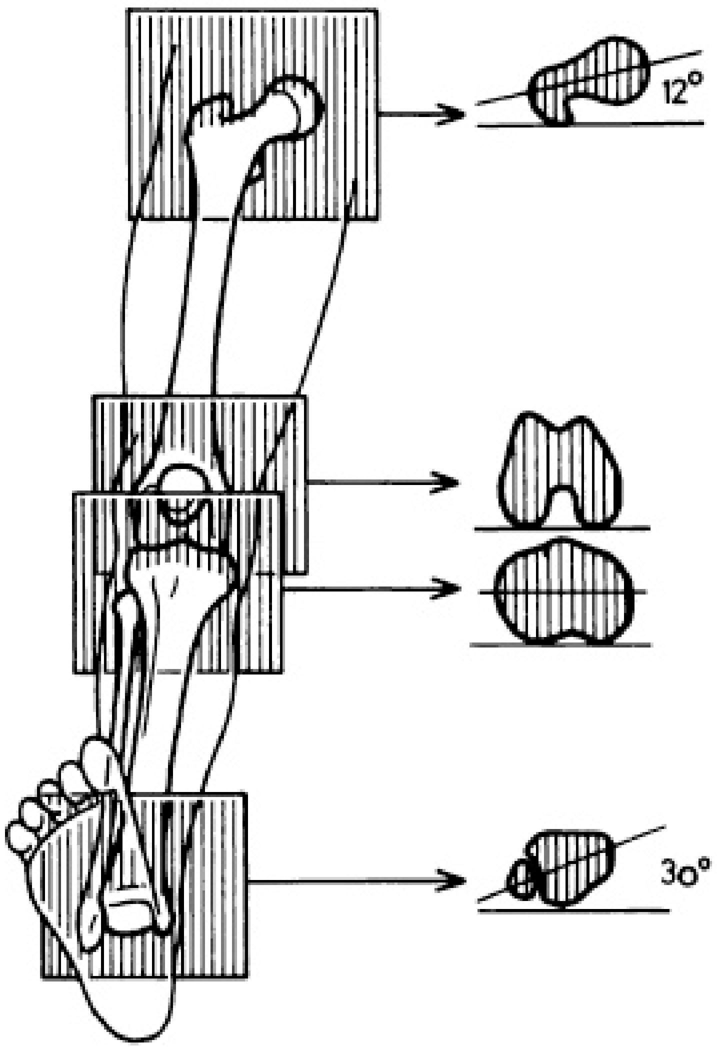

Figure 8: Severe torsional deformities may be assessed with gunsight CT scan by measuring the angle between the transverse axes on CT cuts of the proximal and distal juxta-articular regions

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DISCLAIMER

Interpretation of numbers

Regardless of the language in which the content is displayed, numerals are displayed according to the original English-language numerical separator standard. For example 4 digit numbers shall not include a comma nor a decimal point; numbers of 5 or more digits shall include commas; and numbers stated to be less than 1 shall be depicted using decimal points. See Figure 1 below for an explanatory table.

BMJ accepts no responsibility for misinterpretation of numbers which comply with this stated numerical separator standard.

This approach is in line with the guidance of the International Bureau of Weights and Measures Service.

Figure 1 – BMJ Best Practice Numeral Style

5-digit numerals: 10,000

4-digit numerals: 1000

numerals < 1: 0.25

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