Lower Extremity Abnormalities in Children

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Leg and foot problems in childhood are common causes of parental concern. Rotational problems include intoeing and out-toeing. Intoeing is most common in infants and young children. Intoeing is caused by metatarsus adductus, internal tibial torsion, and femoral anteversion. Out-toeing is less common than intoeing and occurs more often in older children. Out-toeing is caused by external tibial torsion and femoral retroversion. Angular problems include genu varum (bowleg) and genu valgum (knock knee). With pes planus (flatfoot), the arch of the foot is usually flexible rather than rigid. A history and physical examination that include torsional profile tests and angular measurements are usually sufficient to evaluate patients with lower extremity abnormalities. Most children who present with lower extremity problems have normal rotational and angular findings (i.e., within two standard deviations of the mean). Lower extremity abnormalities that are within normal measurements resolve spontaneously as the child grows. Radiologic studies are not routinely required, except to exclude pathologic conditions. Orthotics are not beneficial. Orthopedic referral is often not necessary. Rarely, surgery is required in patients older than eight years who have severe deformities that cause dysfunction. (*Am Fam Physician*. 2017;96(4):226-233. Copyright © 2017 American Academy of Family Physicians.)

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Parents commonly seek medical advice because of concerns about the appearance of their child's lower extremities, feet, or gait.[1,2] Most concerns are normal variations of growth and development and are best managed with parental reassurance.[1] Common normal variants of the lower extremities in children include rotational problems such as intoeing and out-toeing, angular problems such as genu varum (bowleg) and genu valgum (knock knee), and pes planus (flatfoot).

History and Physical Examination

A comprehensive history and physical examination *(Table 1*[3,4] and *Table 2*[4-6]*)* are often sufficient to differentiate normal variations in limb development from pathologic abnormalities, without the need for radiography.[3-5] For the physical examination, the lower extremities should be fully exposed, and the child may need to wear shorts, a diaper, underwear, or a gown.[4-6] The child's height and weight with growth percentiles should be reviewed because normal growth reduces the likelihood of systemic conditions.[5] The musculoskeletal examination should include evaluation for hip dysplasia, leg length discrepancy, and joint laxity *(Figure 1*[5]*)*; assessment of passive range of motion and rotational positioning of the lower extremities (i.e., torsional profile); and a gait analysis *(Figure 2*[5]*)*.

Torsional profile, a key component of the musculoskeletal examination, includes foot progression angle, internal and external hip rotation *(Figure 3*[7]*)*, and thigh-foot angle *(Figure 4*[3,7]*)*. *Figure 5* provides normal ranges for torsional profile measurements.[8] Measurements outside these ranges indicate a pathologic condition.[3-5,7]

Table 1. Pertinent History for Children with Lower Extremity Abnormalities

Understand parental concerns: gait, function, appearance, duration, and progression
Patient history: prenatal and birth history, developmental milestones
Family history: complete orthopedic family history of pathologic rotational or angular deformities and interventions required
Signs/symptoms: gait problems, issues wearing shoes, limping, tripping, falling
Sitting habits: the W sitting position (Figure 8) is common in children with increased femoral anteversion; however, there is no evidence that sitting habits cause or worsen orthopedic lower extremity problems

Information from references 3 and 4.

Table 2. Physical Examination in Children with Lower Extremity Abnormalities

Component	*Findings*	*Possible diagnosis*
Screening examination		
Height and weight	Plot on appropriate Centers for Disease Control and Prevention or World Health Organization growth chart	Abnormal measurements may suggest pathologic conditions (e.g., rickets, metabolic bone disease)
Facial appearance	Abnormal facies	Genetic disorders
Skin	Warmth or redness	Septic arthritis
	Ecchymosis	Fracture, nonaccidental trauma
	Masses; sacral pits, dimples, hair patch; congenital lesions (e.g., café au lait spots)	Spina bifida, neurofibromatosis
Spine	Flexion and extension of the spine	Scoliosis, lordosis, dorsal kyphosis
Neurologic	Neurologic abnormalities	Developmental delay
Focused musculoskeletal examination		
Torsional profile (Figure 5)	External and internal hip rotation (Figure 3)	Measurements more than 2 standard deviations outside the mean may suggest femoral anteversion or retroversion, or internal or external tibial torsion
	Thigh-foot angle (Figure 4)	
Angular measurements	Intercondylar distance: with medial malleoli touching, measure distance between the femoral condyles	Measurements more than 2 standard deviations outside the mean may suggest genu varum or valgum
	Intermalleolar distance: with femoral condyles touching, measure distance between the medial malleoli in sitting position	
Evaluation for limb asymmetry and joint laxity	Measure leg lengths for asymmetry	Asymmetry may be due to contracture, cerebral palsy, perinatal stroke, intracranial mass, neuromuscular disorder, fracture, or septic joint
	Assess range of motion (Figure 1)	Joint laxity can mimic or worsen torsional or angular deformities and contributes to pes planus, hip dysplasia, and dislocated patella
Foot	Heel bisector line (Figure 6)	Metatarsus adductus
	Lateral C shape, tight heel cord	
Gait analysis	Observe child standing for loss of medial foot arch	Pes planus
	Trendelenburg sign (Figure 2)	Hip dysplasia, leg length discrepancy
	Observe child's gait for intoeing and out-toeing, and measure foot progression angle: apply dusted chalk or sanitizing gel to child's bare feet, have child walk on strips of examination paper	Internal or external tibial torsion, femoral anteversion or retroversion
	Assess for W sitting position (Figure 8)	Femoral anteversion

Information from references 4 through 6.

Foot progression angle measurements will have positive values with out-toeing and negative values with intoeing.[4,5] Evaluation of hip rotation shows increased internal rotation with femoral anteversion and increased external rotation with femoral retroversion.[3,4] Thigh-foot angle testing is positive for tibial torsion when the foot turns in relative to the thigh axis.[9]

Evaluation of genu varum and genu valgum involves additional measurements, including intercondylar distance for genu varum and intermalleolar distance for genu valgum. The heel bisector line *(Figure 6)* should be assessed to evaluate for foot deformities such as metatarsus adductus.[3,10]

Clinical Conditions

Lower limb abnormalities in children can be grouped broadly into three categories: rotational, angular, and foot variations *(eTable A)*.

INTOEING

Intoeing, an inward pointing foot, is the most common rotational condition in children. The three major causes of intoeing are metatarsus adductus, internal tibial torsion, and femoral anteversion.[11] The etiology of intoeing is suggested by the age at the onset of symptoms.[12]

Metatarsus Adductus. Metatarsus adductus is the most common congenital foot abnormality and usually

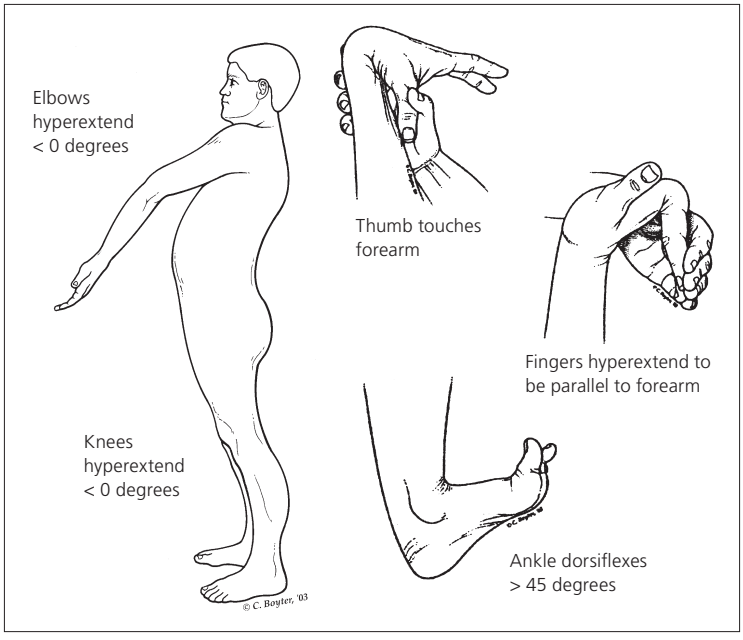

ILLUSTRATION BY CHARLES H. BOYTER

Figure 1. Joint laxity. Assess for the ability to hyperextend elbow or knees, touch thumb to forearm, extend fingers at metacarpal joint parallel to forearm, or dorsiflex ankle greater than 45 degrees. Normal ankle dorsiflexion is 20 degrees, and normal plantar flexion is 50 degrees.

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resolves spontaneously by one year of age.[13] Physical examination reveals medial deviation of the forefoot relative to a normal hindfoot, lack of a tight heel cord, a convexity or C shape of the lateral aspect of the foot, and a concave medial border of the foot[3,12] *(Figure 7)*. Severity is determined by the heel bisector line. The foot should be assessed for flexibility to rule out rigid deformities (e.g., metatarsus varus). Treatment is based on severity and age.[12] Flexible metatarsus adductus does not require treatment.[14,15] Severe metatarsus adductus and rigid deformities are treated with serial casting.[3,5] Adjustable shoes are effective in prewalking infants who have motivated parents and are less expensive than serial casting.[14,16,17]

Rigid metatarsus adductus is ideally treated with serial casting. This is most feasible in children who are not yet walking. Older children or those with persistent symptomatic metatarsus adductus resistant

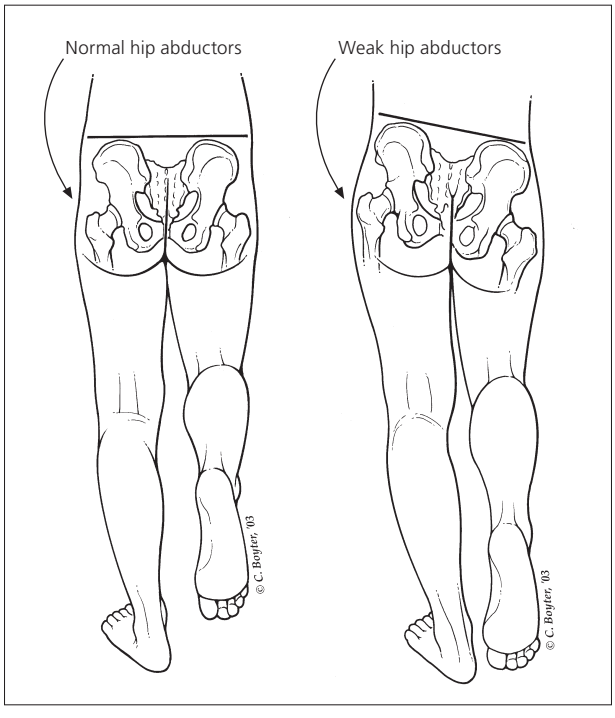

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Figure 2. Trendelenburg sign. The pelvis tilts toward the normal hip when bearing weight on the affected side. It is commonly positive in the setting of hip dysplasia or leg length discrepancy.

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Figure 3. Hip rotation. Child lying prone with knees bent for evaluation of *(A)* external rotation and *(B)* internal rotation. External hip rotation is increased with femoral retroversion, and internal hip rotation is increased with femoral anteversion. Femoral anteversion is graded by severity of internal hip rotation: mild is 70 to 80 degrees, moderate is 80 to 90 degrees, and severe is greater than 90 degrees.

Information from reference 7.

Figure 4. Thigh-foot angle. A child lying prone with knees bent for assessment of the thigh-foot angle. The hindfoot is held in a neutral position and the axis of the thigh is compared with the axis of the foot. The normal thigh-foot angle is more than 10 to 15 degrees of external rotation and may be up to 30 degrees in young children.

Information from references 3 and 7.

to casting may require surgery if the deformity causes significant dysfunction. Surgery for metatarsus adductus has high failure and complication rates, and thus casting or adjustable shoes are generally attempted first, before the child starts walking. Casting in older children who are walking is often not a feasible option, and surgical consultation may be appropriate to discuss risks and benefits of surgery. Most cases of persistent metatarsus adductus are still asymptomatic in adulthood, and surgery is rarely indicated.[3,4,12,18]

Internal Tibial Torsion. Internal tibial torsion is a common normal rotational variant.[3,19] It is the most common cause of intoeing,[5,6] usually presenting in toddlers. The child walks with patellae facing forward and feet pointing inward, producing an internally rotated

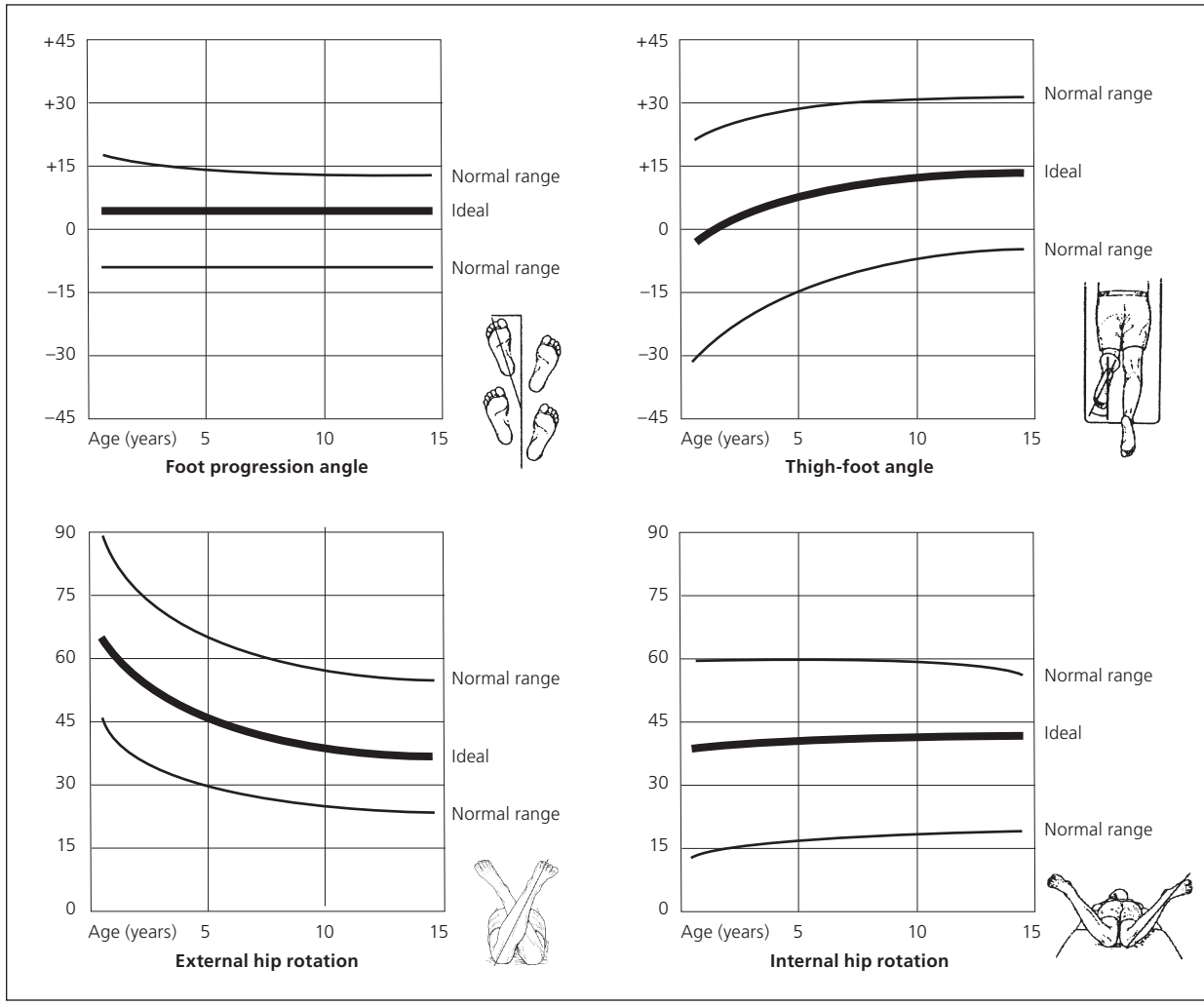

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Figure 5. Torsional profile. Measurements more than 2 standard deviations outside the mean are considered abnormal (i.e., a deformity). Measurements within the normal range do not require subspecialty consultation.

Adapted with permission from Wenger DR, Rang M. The Art and Practice of Children's Orthopaedics. *New York, NY: Raven Press; 1993.*

thigh-foot angle and negative foot progression angle on torsional profile.[4,5] Internal tibial torsion usually resolves spontaneously by five years of age.[4] Braces, night splints, shoe modification/wedges, other orthotics, and serial casting are not recommended for this condition.[3] Residual internal tibial torsion has not been shown to cause degenerative joint disease or disability and, thus, surgery is rarely indicated.[3,4] Surgery may be considered in patients older than eight years who have a severe residual deformity (thigh-foot angle more than three standard deviations above the mean [i.e., greater than 15 degrees internal rotation]) and severe functional or cosmetic abnormality that is not expected to self-correct.[3,18,20]

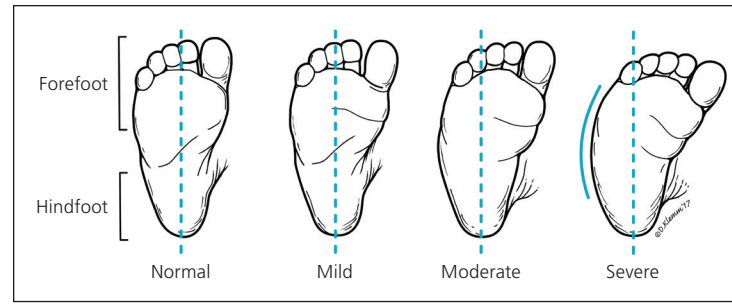

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Figure 6. Heel bisector line. This line is used to evaluate for metatarsus adductus, a cause of intoeing. It is performed with the patient prone and knees flexed at 90 degrees, using an imaginary straight line from the heel to the forefoot. Normally, the line that bisects the heel falls on the second toe. Metatarsus adductus is mild if the line falls on the third toe, moderate if it falls between the third and fourth toes, and severe if it falls between the fourth and fifth toes.

Femoral Anteversion. Femoral anteversion is the most common cause of intoeing in school-aged children and is most severe between four and seven years of age.[3,19,20] Physical examination focuses on assessment of internal and external rotation of the hip. Increased internal rotation (60 to 90 degrees) with reduced external rotation (10 to 15 degrees) is diagnostic of femoral anteversion. The patellae and feet appear to point inward (known as squinting or kissing patellae), resulting in a clumsy, circumduction gait.[4,5,12] Children with femoral anteversion often sit in the W position *(Figure 8)* for comfort rather than sitting cross-legged.[4,12] Spontaneous resolution occurs in more than 80% of children by eight years of age.[4,5,12] Special shoes, braces, connective bars, and other orthotics are not effective.[3-5,12,21] Surgical intervention is indicated for children older than eight years with severe functional or cosmetic abnormality secondary to persistent femoral anteversion greater than 50 degrees and internal rotation greater than 80 degrees.[4,12]

OUT-TOEING

Out-toeing, an outward pointing foot, is less common than intoeing. It is caused by external tibial torsion, femoral retroversion, and pes planus.[3,5]

External Tibial Torsion. External tibial torsion usually presents between four and seven years of age when the tibia externally rotates during normal growth and worsens into a deformity. Physical examination reveals a positive foot progression angle and a thigh-foot angle greater than 30 degrees[3,4] *(Figure 9)*. Surgery to correct external tibial torsion is rarely recommended before 10 years of age, but may be performed to prevent disability from patellofemoral syndrome and knee joint instability. Surgery can have a high complication rate.[3,4,11]

Femoral Retroversion. Femoral retroversion is common in newborns because of contracture of the hip from intrauterine positioning.[5,9,11] It is diagnosed when the feet of a prewalking child are rotated outward by nearly 90 degrees (i.e., Charlie Chaplin appearance).[5,9,11] There is a markedly decreased hip internal rotation and increased external rotation on torsional profile.[3,4]

Femoral retroversion typically improves during the first year of walking.[9] Persistence after three years of age warrants radiography of the pelvis, hips, and lower extremities and referral to an orthopedist.[11] If femoral retroversion is diagnosed after eight years of age, it may be associated with a slipped capital femoral epiphysis.[3,11] Femoral retroversion results in osteoarthritis and

Figure 7. Metatarsus adductus.

Figure 8. The W sitting position is common in children with increased femoral anteversion.

Figure 9. External tibial torsion.

increased risk of lower extremity stress fracture.[11] Surgical consultation should be considered for children with persistent femoral retroversion at three years of age[5]; however, the average age for surgical correction with osteotomy is 10 years of age.[3,11]

Pes Planus. Pes planus, or flatfoot, is the absence of the medial longitudinal arch on weight bearing and presence of the arch with tiptoeing[3] *(Figure 10)*. Physiologic flatfoot that is flexible is a benign, normal variant.[6,22,23] Pathologic flatfoot is rigid and requires orthopedic referral.[6,22,23] Physiologic flatfoot is observed in nearly all infants, 45% of preschool-aged children, and about 15% of persons older than 10 years.[6,24] Most children with physiologic flatfoot are asymptomatic and develop an arch before 10 years of age.[3,23] Painless, flexible flatfoot does not require investigation or intervention.[3,6,22,23] Orthotics such as special shoes and insoles are not effective for painless pes planus.[3,6,22,23] Pes planus should be distinguished from tarsal coalition in adolescents.[3,23] On examination, limited movement of the subtalar joint and absence of the medial arch with tiptoeing suggest tarsal coalition, which requires further investigation with oblique radiography or computed tomography.[3,23]

Surgical consultation is recommended for patients with tarsal coalition and symptomatic pes planus (rigid type and flexible type with persistent pain and dysfunction despite previous nonoperative treatments). Nonoperative treatments for symptomatic flexible pes planus include rest, activity modification, massage, physical therapy, and a trial of a nonsteroidal anti-inflammatory drug. Although orthotics are ineffective at altering the course of flexible flatfoot, they may provide relief of pain when present and may also be tried before surgical management.[22]

Figure 10. Pes planus (flatfoot).

ANGULAR VARIATIONS

During childhood, knee alignment changes with skeletal growth and development. At birth, most newborns have physiologic genu varum.[4] This gradually progresses to a neutral position by two years of age and then to physiologic genu valgum between three and six years of age. By seven to 11 years, most children's knees return to a neutral or slightly valgus position. Girls tend to have more valgus positioning than boys.[25-28]

SORT: KEY RECOMMENDATIONS FOR PRACTICE

Clinical recommendation	*Evidence rating*	*References*
Radiography is not needed in the initial evaluation to differentiate normal variations in childhood limb development from pathologic lower extremity abnormalities.	C	2-7, 9, 12
The physical examination for lower extremity abnormalities should include measurements of height and weight with growth percentiles; inspection of the face, skin, and neurologic system; and focused musculoskeletal examination, including torsional profile and angular measurements.	C	3-6
Discussions with parents should focus on the natural course of lower extremity abnormalities and include reassurance; most rotational and angular concerns resolve spontaneously if measurements are within two standard deviations of the mean.	C	1-5, 12, 18-21, 25-28, 30, 31
Lower extremity rotational and angular abnormalities that are two standard deviations outside the mean or that persist beyond the expected age of resolution should be referred to an orthopedic surgeon.	C	3, 5, 11, 21, 25-28
Orthotics are not effective in the treatment of lower extremity rotational and angular abnormalities.	C	3-5, 20
Adjustable shoes are effective for the treatment of metatarsus adductus in prewalking infants with motivated parents and are less expensive than serial casting.	B	10, 14, 16, 17
Adolescents with rigid or symptomatic flexible pes planus should receive imaging of the feet and referral to a podiatrist or orthopedist.	C	6, 22-24

A = consistent, good-quality patient-oriented evidence; B = inconsistent or limited-quality patient-oriented evidence; C = consensus, disease-oriented evidence, usual practice, expert opinion, or case series. For information about the SORT evidence rating system, go to http://www.aafp.org/afpsort.

Parental concerns for knee misalignment are often because of appearance, awkward gait, or clumsiness. Normal, transient physiologic angulation should be distinguished from pathologic processes. Evaluation of standing knee alignment includes the intercondylar and intermalleolar distances, and the tibiofemoral angle measured with a goniometer.[4,26] Severe deformity, unilateral or asymmetric presentation, and concerns for metabolic or endocrine disorders warrant further workup.

Figure 11. Genu varum (bowleg).

Genu Varum. Genu varum *(Figure 11)* is typically bilateral, symmetric, and self-limited. Bracing, connective bars, and other orthotics are not necessary for most patients. Persistence after two years of age is unusual. Adolescents who participate in high-impact sports may develop genu varum.[29] Pathologic genu varum may be due to rickets, skeletal dysplasia, or Blount disease (abnormal growth of medial proximal tibial physis that is associated with obesity).[4,30,31]

Genu Valgum. Genu valgum commonly occurs between three and six years of age and is self-limited. Onset in adolescence is unusual and warrants investigation. Pathologic causes of genu valgum include trauma or fracture, prior osteomyelitis, and possibly obesity.[32]

Treatment of Angular Variations. Pathologic genu varum and valgum may be associated with early osteoarthritis.[29,32] Surgical correction of genu varum and valgum is reserved for when the condition does not spontaneously resolve, conservative measures are ineffective, or there is extreme angulation. Surgical techniques attempt to realign the bone or reorient bone growth.[33]

This article updates a previous article on this topic by Sass and Hassan.[5]

Data Sources: A PubMed search was completed using Clinical Queries and the Therapy Narrow Filter with the terms pediatric, lower extremity abnormality, lower extremity variant, metatarsus adductus, genu valgum, genu varum, tibial torsion, angular deformity, intoeing, and out-toeing. The search included randomized controlled trials, clinical

trials, and reviews. Also searched were Essential Evidence Plus and the Cochrane Database of Systematic Reviews. Search dates: December 2015 to February 2016, and April 2017.

Figures 7, and 9 through 11 courtesy of Courtney Holland, MD.

The opinions and assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the U.S. Army Medical Department or the U.S. Army Service at large.

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eTable A. Summary of Lower Extremity Conditions in Children

Condition	*Epidemiology*	*Common features*	*Diagnostic measurements*	*Management*
Rotational				
Intoeing[A1]	Occurs in 2 out of 1,000 live births; more common than out-toeing	Toes pointing inward	Negative foot progression angle	Parental reassurance Surgical referral needed only for deformities measuring more than 2 standard deviations outside the mean
Metatarsus adductus[A1-A10]	Presents by 1 year of age Occurs more often in boys, twins, and premature infants Occurs in 1 out of 200 to 1,000 live births; 1 out of 20 siblings of children with metatarsus adductus are also born with the condition 2% of cases are associated with hip dysplasia	Usually diagnosed in infancy Likely caused by intrauterine positioning Usually bilateral; left sided when unilateral Lateral C- or kidney-shaped foot	Heel bisector line Flexibility assessment: holding the heel in neutral position, the forefoot should abduct to at least the neutral position, and the ankle should have normal range of motion; if the forefoot does not abduct to neutral, the foot deformity is rigid (e.g., metatarsus varus)	Parental reassurance (usually resolves spontaneously by 1 year of age) Treatment and radiography are not indicated for flexible metatarsus adductus Adjustable shoes or serial casting is the preferred treatment for severe metatarsus adductus in children who are not yet walking; serial casting is usually biweekly for 6 to 8 weeks; full-leg and below-knee casts are equally effective Adjustable shoes are as effective as casting; surgical consultation may be considered in older children if there is parental concern about compliance with adjustable shoes or casting Surgical correction of persistent metatarsus adductus has high failure and complication rates; persistence into adulthood causes no long-term disability, thus surgery is reserved for severe, rigid metatarsus adductus that affects shoe wear and function
Internal tibial torsion[A1,A2,A11-A14]	Presents between 2 and 4 years of age Affects boys and girls equally	Most common cause of intoeing, usually presenting in toddlers Possibly caused by intrauterine positioning Frequent falls Usually bilateral; left sided when unilateral Patellae facing forward and feet pointing inward	Thigh-foot angle Foot progression angle Transmalleolar axis (copresentation of genu varum and/or patient is younger than 3 years)	Parental reassurance (usually resolves spontaneously by 5 years of age) Radiography not recommended unless rickets, Blount disease, or skeletal dysplasia is suspected Braces and other orthotics are ineffective Surgery may be considered in patients older than 8 years if thigh-foot angle is internally rotated more than 3 standard deviations above the mean (or greater than 15 degrees) and there is severe functional or cosmetic abnormality
Femoral anteversion (increased femoral internal rotation)[A1,A2,A14,A15]	Presents between 4 and 7 years of age More common in girls Hereditary	Usually bilateral Children sit in a W position for comfort Inward pointing feet and patellae (squinting or kissing patellae) Clumsy, circumduction gait	Internal and external hip rotation	Parental reassurance (usually resolves spontaneously by 8 years of age) Radiography not recommended Braces and other orthotics are ineffective Surgery may be considered in patients older than 8 years with severe functional or cosmetic abnormality
Out-toeing[A1,A2,A16]	Less common than intoeing	Toes pointed outward	Positive foot progression angle	Parental reassurance and watchful waiting
External tibial torsion[A1,A2,A16]	Presents between 4 and 7 years of age Affects boys and girls equally	Usually bilateral; right sided when unilateral Charlie Chaplin appearance	Thigh-foot angle	May not resolve without treatment; tibia rotates laterally with normal childhood growth, worsening the condition as the child ages Disability can result from patellofemoral syndrome and knee instability Surgery may be considered after 10 years of age
Femoral retroversion (increased femoral external rotation)[A1,A2,A16]	Affects all ages, especially young infants More common in boys	Likely caused by intrauterine positioning Unilateral, right sided Seen most often in newborns and obese children	Thigh-foot angle Rule out slipped capital femoral epiphysis Decreased hip internal rotation and increased hip external rotation	Parental reassurance and watchful waiting Typically resolves within the first year of walking; persistence after 3 years of age warrants radiography Disability often results from osteoarthritis, stress fractures, and slipped capital femoral epiphysis Surgery may be considered after 3 years of age

continues

eTable A. Summary of Lower Extremity Conditions in Children *(continued)*

Condition	*Epidemiology*	*Common features*	*Diagnostic measurements*	*Management*
Angular				
Genu varum (bowleg)[A1,A2,A17-A20]	Presents by 2 years of age Affects boys and girls equally	Bilateral, symmetric Athletes participating in high-impact sports	Intercondylar distance Rule out rickets, skeletal dysplasia, Blount disease	Parental reassurance (usually resolves spontaneously by 4 years of age) Nonsurgical interventions are not recommended Surgery reserved for extreme angulation (more than 2 standard deviations outside the mean)
Genu valgum (knock knee)[A1,A2,A17-A20]	Presents between 3 and 6 years of age More common in girls	Bilateral	Intermalleolar distance Pathologic causes include trauma, fracture, prior osteomyelitis	Usually resolves spontaneously, but surgery may be required
Foot				
Pes planus (flatfoot)[A1,A3,A21-A26]	All ages Hereditary	Usually bilateral Associated with joint laxity, obesity, and wearing shoes Most cases are flexible and asymptomatic	Absence of the medial longitudinal arch on weight bearing and presence of the arch with tiptoeing Rule out tarsal coalition in adolescents	Pes planus is usually flexible and asymptomatic, and resolves spontaneously Flexible pes planus that does not resolve by 10 years of age is usually still asymptomatic Flexible pes planus that causes pain should first be treated with nonsurgical interventions; although these interventions are not effective at altering the natural course of pes planus, there is limited evidence that they help to relieve pain and improve balance and function Consider referral to orthopedics or podiatry for adolescents or adults with flexible painful pes planus that does not respond to nonsurgical interventions Obtain imaging if there is concern for rigid pes planus or tarsal coalition based on examination findings; surgical referral is indicated for rigid pes planus and tarsal coalition

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