Normal lower limb variants in children

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Bow legs, knock knees, flat feet, intoeing, and out-toeing gaits in children are common but often cause undue parental anxiety, prompting frequent visits to general practice. A substantial proportion of referrals to paediatric orthopaedic clinics consist of normal physiological variants in growing children. Our review aims to assist general clinicians in recognising normal physiological variants in the lower limbs of children and to identify abnormal features that require specialist attention.

Why are normal limb variants important?
Musculoskeletal symptoms are one of the leading causes of visits to primary care doctors and such visits are on the increase. One in eight children each year visits a doctor for a musculoskeletal disorder. Normal variants form an important proportion of secondary care referrals. Many parents seek medical attention for the appearance of their child’s lower limbs, or with concerns that their child’s condition may lead to degenerative musculoskeletal problems or a reduction in their sporting ability. In most cases the problem is a variation of normal development, which follows a benign and predictable course. Rarely does the problem persist into adolescence or require treatment.

A Cochrane review of interventions to improve outpatient referrals from primary to secondary care suggested that passive dissemination of referral guidelines was ineffective. An effective strategy may be to combine educational activities championed by consultant specialists (in this case, paediatric orthopaedic surgeons or rheumatologists) in combination with structured referral guidelines.

How are normal variants assessed?
It is crucial to elucidate the reason for consultation and identify parental concerns—for example, pain, long term disability, cosmesis, awkward walking or running, frequent trips or falls. Occasionally, rotational or angular malalignment are the presenting symptoms of underlying disorders (table); for example, children with mild spastic hemiparesis (cerebral palsy) may present with unilateral intoeing.

To manage the problem effectively, it is essential to determine the level of the deformity, as it may occur anywhere between the foot and the hip. Two or more deformities may be additive or compensate for each other. Examination of children’s rotational and angular profiles should therefore proceed in a sequential fashion (box 1).

What are the different normal variants seen in clinical practice?
Lower limb variants can be broadly divided into rotational (intoeing and out-toeing gait) and angular ( genu valgum and genu varum) deformities.

Rotational deformities
The child’s rotational profile is a composite of measurements of the lower limbs—that is, rotational range of the hips and rotational alignment of the tibia and foot. The most obvious manifestation is the position of the feet—commonly referred to as “intoeing” or “out-toeing.” Figure 1 on the bmj.com shows the normal range of rotational motion.
**Box 1 | Musculoskeletal examination of a typical child**

- **Weight**
- **Height**

**Rotational profile (especially if a child has an in-toeing or out-toeing gait)**
- Observe gait and foot-progression angle (angle the axis of the child’s foot makes with the direction in which he or she is walking)
- Observe child standing (squinting patella of femoral anteverision; flat foot), sitting (“W” position), running (running accentuates the problem), and lying down
- Shape of foot (heel bisector line—normal between second and third toes)
- Tibial rotation (thigh-foot angle)—prone position with knees flexed to 90° and measure the angle the foot makes with the thigh
- Femoral rotation—prone position with knees flexed to 90°; hip rotation is generally symmetrical in internal and external rotation
- Hypermobility (Beighton score)

**Angular profile (especially in the presence of knocked knees or bow legs)**
- Distance between knees while standing and lying with the ankles together (normal intercondylar distance <6 cm)
- Distance between ankles while standing and lying with the knees together (normal intermalleolar distance <8 cm)

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**Intoeing gait (“pigeon-toed” gait)**

There are three main causes of an in-toeing gait: metatarsus adductus, internal tibial torsion, and increased femoral anteverision.

**Metatarsus adductus**

Metatarsus adductus is the most common congenital foot deformity, occurring in 1 in 1000 births. It is defined as an internal angulation of the forefoot (or metatarsals) on a neutral or flexible hindfoot. Clinically, the foot has a curved border and an abnormal heel bisector line (fig 2). In a study of 379 children with metatarsus adductus, nearly 90% required no treatment. No study has proved the effectiveness of passive stretching or corrective shoes for the flexible, benign forms; therefore, these may be allowed to resolve naturally. For the rigid type, and cases that do not resolve by age 6-9 months, serial casting may be of value.

**Internal tibial torsion**

Internal tibial torsion is the most common cause of in-toeing. It is defined by the angular difference between the transmalleolar axis of the ankle and the bicondylar axis of the knee. Clinically, the feet are internally rotated while the patella remains in neutral position (fig 3). Internal tibial torsion is most apparent when infants first begin to walk, and parents may mention that their child trips frequently and appears clumsy. The condition affects both sexes equally, is bilateral in two thirds of affected infants, and is associated with metatarsus adductus in about one third. Varus at the knee, either physiological or disease related (such as in Blount’s disease), is often associated with internal tibial torsion.

The clinical course is of spontaneous resolution—the transmalleolar axis rotates laterally from 2-4° at birth to 10-20° in adulthood. Resolution is most rapid in infancy. Treatment with orthotic devices is unnecessary and ineffective. In severe cases that cause functional disability, such as frequent trips and falls, tibial rotational osteotomy may be considered in older children (>10 years).

**Femoral anteverision**

Femoral anteverision is defined as the angular difference between the axis of the femoral neck and the transcondylar axis of the knee. The natural femoral anteverision has been well documented in a 20 year follow-up study of 1148 hips. On average, femoral anteverision is 40° at birth, decreasing throughout growth to 16° in adulthood.

Femoral anteverision is most pronounced between 4 and 6 years of age. It is twice as common in girls and is nearly always symmetrical. It is also often familial. Children sit with their limbs in the “W” position (fig 4), walk with an in-toeing gait with the patella pointing inwards (“squinting patella”), and run in an awkward pattern (“eggbeater” pattern, with inward rotation of the thighs and outward rotation of the legs and feet). Intoeing typically becomes more pronounced when children are tired. Tripping as a result of crossing feet may occur.

Femoral anteverision spontaneously resolves in more than 80% of affected children by late childhood.
Flexible pes planus (flat feet)

The foot is the most common region prompting medical attention for musculoskeletal problems in children, with 90% of concerns related to flat feet. The prevalence of flat feet inversely correlates with age—about 45% in children aged 3-6 years, decreasing to 2-16% in older children.

Neonates and toddlers universally have “flat feet” owing to the presence of a fat pad beneath the medial longitudinal arch. Additionally, intrinsic laxity and the lack of neuromuscular control in children starting to mobilise result in flattening of the foot when weight bearing. This typically resolves between the ages of 4 and 8 years.

Clinically, the heel is in valgus, with sagging of the medial arch (fig 6). A careful assessment should be made to differentiate a flexible flat foot from a rigid one, with the latter encompassing <1% of children, which is usually painful and caused either by tarsal coalitions (presentation is typically in adolescence), congenital vertical talus, or inflammatory disorders (pes planus is a common feature of juvenile idiopathic arthritis). The medial arch of a flexible flat foot reconstitutes on tiptoeing (fig 6) or when the foot is dependent. Children rarely have symptoms, with parental concern mainly related to cosmesis or the misconstrued belief that the condition could lead to pain or functional problems in later life.

Risk factors include hyperlaxity, obesity, and a positive family history. Examination may reveal the flat foot to be severe and causing the shoe to become deformed.

Most flexible flat feet are physiological, asymptomatic, and require no treatment, although other neurological (cerebral palsy), muscular (muscular dystrophy), syndromic (trisomy 21), or connective tissue (Marfan's and Ehlers-Danlos syndromes) disorders should be actively sought. Some cases of flexible flat feet may be painful, with more specific problems after activity.

The treatment of paediatric flat foot has been controversial and debate is still ongoing with no current ideal intervention. Historically, various devices (for example, high top shoes) were used to correct and prevent such deformities. The consensus now is that the asymptomatic flexible flat foot is benign.
and warrant specialist referral for further investigation, where typically long leg alignment radiographs are taken (fig 8). Box 2 lists the possible causes of both conditions.

**Genu varum (bow legs)**
Physiological genu varum is thought to relate to intrauterine positioning, which leads to the contracture of the medial knee joint capsule. There is no evidence for the efficacy of foot orthoses or any other non-surgical intervention. In children with symptoms, expert opinion favours the use of a well moulded insole, which does not correct the flat foot but alleviates pain and prevents shoe deformation.

**Angular deformities**
Angular alignment refers to the tibiofemoral angle, which can be clinically assessed by the intermalleolar and intercondylar distances (fig 7). Angular deformities (for example, genu varum and genu valgum) tend to be symmetrical and cause no pain. Clinical examination should focus on excluding rotational abnormalities and ligamentous laxity as these can exaggerate the appearance of angular deformities.

Disease should be considered in cases where the deformity is unilateral, asymmetrical, severe, progressive, or accompanied by short stature. Genu varum in children aged more than 3 years or genu valgum in children aged less than 2 years should also raise concern and warrant specialist referral for further investigation, where typically long leg alignment radiographs are taken (fig 8). Box 2 lists the possible causes of both conditions.

**Box 2: Causes of genu varum and genu valgum**

**Genu varum**
- Blount’s disease
- Metabolic (for example, rickets, renal osteodystrophy)
- Post-traumatic
- Post-infection (for example, osteomyelitis)
- Skeletal dysplasias (for example, achondroplasia, osteogenesis imperfecta, metaphyseal chondrodysplasia)
- Tumours

**Genu valgum**
- Idiopathic
- Metabolic (for example, rickets, renal osteodystrophy)
- Obesity
- Post-traumatic (for example, proximal tibial metaphyseal fracture)
- Post-infection
- Neuromuscular
- Congenital (for example, fibular dysplasia)
- Skeletal dysplasias (for example, pseudoachondroplasia, multiple epiphyseal dysplasia)
- Tumours

**Fig 6** | Child with bilateral flexible flat feet and fallen medial arches, hyperpronation of foot (left) and valgus heels (middle, red line showing outward tilting of both heels) with “too many toes” sign. However, on tiptoe, the medial arch reforms (right)
an increased risk of injury and osteoarthritis in later life. Further studies are required to find preventive solutions to this relation. There is currently no specific advice that can be given to such high performance adolescents who present with knee varus. However, those who present with concurrent knee pain should be investigated for alternative injuries—for example, meniscal injury, osteochondritis dessicans, or ligamental injury.

Genu valgum (knock knees)

Referrals for knock knees are common in children aged between 3 and 4 years. Knock knees can be accentuated by obesity, ligamentous laxity, and flat feet. In addition, torsional deformities such as femoral anteversion with compensatory external tibial torsion may make a physiological genu valgum appear more severe. The intermalleolar distance is measured with the knees in contact and should be less than 8 cm. Treatment of physiological genu varum and valgum involves reassurance and observation.

What else should be considered?

Vitamin D deficiency

There is a resurgence of nutritional rickets secondary to vitamin D deficiency in children from ethnic minority groups and white children in Europe and Australasia. Lower limb deformities have been attributed to vitamin D or calcium deficiency, or both. Genu varum is typical of rickets, but genu valgum can also occur.

Vitamin D insufficiency has been a recent focus of the UK Department of Health (the “Healthy Start” supplements and National Institute for Health and Care Excellence guidelines). A comprehensive review on the diagnosis and management of vitamin D deficiency can be found elsewhere.

Obesity

Globally, the prevalence of obesity is increasing. Current evidence points to a negative effect of obesity on the musculoskeletal health of children. An increased body mass index in children has been identified as a predictor for musculoskeletal problems, with knee and foot pain the most commonly reported symptoms. Children who are overweight or obese show alterations in standing balance, postural adjustment, and movement efficiency, which has been proposed to contribute to the development of lower limb angular deformities and premature osteoarthritis.

Several studies have found a positive relation between body mass index and genu valgum and flat feet. Similarly, there are positive associations between childhood obesity and conditions such as Blount’s disease (fig 9) and slipped capital femoral epiphysis. Blount’s disease is a growth disturbance of the medial portion of the proximal tibial growth plate. It can occur at any age from birth to skeletal maturity. Slipped capital femoral epiphysis, on the other hand, typically occurs during adolescence. It is a disorder of the proximal femoral growth plate (physis), leading to displacement of the femoral neck from the femoral head.