Intoeing gait in children

YH Li, JCY Leong

Objective. To review the aetiology and management of intoeing.
Data sources. *Medline* and non-*Medline* literature search, and personal experience.
Study selection. Studies that provided evidence-based information about the aetiology and management of paediatric intoeing gait were selected.
Data extraction. Data were extracted and reviewed independently by both authors.
Data synthesis. An intoeing gait affects many children and, as with flexible flatfoot, bowleg, and knock-knee, it falls into the category of physiological problems that occur in normal children. The usual causes are excessive femoral anteversion, internal tibial torsion, and metatarsus adductus. Management is based on understanding the causes and the natural course of the condition and the effectiveness of various treatment modalities. Unfortunately, due to a poor understanding of the condition, intoeing is commonly overtreated with braces or special footwear.
Conclusions. Intoeing is one of the most common conditions encountered in paediatric orthopaedic practice. It is important to make an early diagnosis of pathological causes of intoeing such as cerebral palsy and developmental dysplasia of the hips so that treatment can be commenced as soon as possible.

HKMJ 1999;5:360-6

Key words: Child; Foot deformities, congenital; Gait; Hip joint/physiology; Movement

Terminology

Rotation refers to the twist of the femur or the tibia about the long axis of each bone. Rotation that is normal in direction and magnitude is defined as 'version' and that which is abnormal is termed 'torsion'. Furthermore, 'normal' is defined as plus or minus two standard deviations from the mean.[1]

Rotation of a bone is determined by the angle between reference axes at the proximal and distal ends of each bone. Rotation of the femur, for instance, is the angle between the axis of the head/neck and the axis of the distal condyles at the most posterior points. If the angle between the proximal and distal axes is positive, the femur is 'anteverted'. If the angle between the proximal and the distal axes is negative, the femur is 'retroverted'. If the angle is greater than two standard deviations from the mean, then the femur will demonstrate torsion. Tibial version or torsion is the angle measured between the transmalleolar axis and the bicondylar axis of the proximal tibia at the knee.

Duchess of Kent Children's Hospital, 12 Sandy Bay Road, Sandy Bay, Hong Kong
YH Li, FRCS (Edin), FHKAM (Orthopaedic Surgery)
Department of Orthopaedic Surgery, The University of Hong Kong, Queen Mary Hospital, Pokfulam, Hong Kong
JCY Leong, FRCS (Edin), FHKAM (Orthopaedic Surgery)

Correspondence to: Dr YH Li

The embryology of lower-extremity version

A basic knowledge of the embryological and foetal development of the musculoskeletal system is important in the understanding of lower-extremity version. The lower-extremity limb buds first appear as paddle-shaped buds during the fifth to sixth weeks of gestation. The early limb bud continues its formation by the migration and proliferation of the differentiating mesenchymal tissues. By the end of the sixth week, the limb buds have flattened and formed terminal hand and foot plates and the early external form of the limb. At approximately 7 weeks, the longitudinal axes of the upper and lower limb buds are parallel. The pre-axial components face dorsally and the post-axial borders face ventrally. In this period, the position of the limb buds relative to the trunk change in a predetermined manner not related to muscle activity or inherent osseous torsion. The upper limb buds rotate externally and the lower buds internally, bringing the great toe to the midline from its initial post-axial position. Afterwards, mechanical intrauterine moulding of the lower limbs of the foetus takes place, causing the femurs to rotate externally and the tibiae to do so internally.[2-4]

Femoral anteversion at birth is about 30 to 40°. Because of the common intrauterine position of hip external rotation, the infant appears on examination to have more hip external rotation than internal rotation. This soft tissue external hip rotation contracture decreases over the first year of life and the increased hip internal rotation expected from the femoral anteversion starts to become apparent. There is a gradual decrease in femoral anteversion from 30 to 40° at birth to the value of 10 to 15° by early adolescence, with most of this improvement occurring before 8 years of age.[5]

In a computed tomography (CT) study of tibial torsion in the growing fetus, it was found that there was an increase in external tibial torsion in the early stages of foetal life but that this gradually decreased so that in the newborn, the tibial torsion was internal. After birth, the tibia rotates externally and the average version of the tibia at skeletal maturity is 15°.[6]

Causes of an intoeing gait

In the infant, the most common cause is metatarsus adductus. With this condition, the entire forefoot is adducted at the tarsometatarsal level but the hindfoot is in its normal position. When present in the second year of life, intoeing is commonly due to internal tibial torsion. After 3 years of age, this problem is usually due to excessive femoral anteversion. When a child toes-in severely, a combination of causes should be suspected.

Sometimes a rotational problem is a manifestation of an underlying disorder such as cerebral palsy and hip dysplasia. Before focusing on the rotational problem, a physician must check that the rest of the musculoskeletal system is normal. Any clinical findings such as abnormal muscle tone, gait abnormality, limitation of hip abduction, and leg length discrepancy should prompt a more intensive evaluation.

Performing an evaluation

Taking a history

Intoeing is extremely common in infants and children and is a frequent cause of anxiety in parents. It is important to identify the reason for the consultation and what the parents' concerns are; the parents' concerns must be taken seriously. In addition, is it the child's present problem or fear that the current problem will persist and cause some long-term disability such as arthritis[7,8] or make it difficult for the child to participate in sports or function normally? Enquire about any family history of rotational problems. Take a developmental history and ask about the nature of the disability such as tripping or falling. Find out if the child prefers to sit on the floor in the 'W' or reversed tailor position.

The physical examination

When evaluating a patient with a rotational abnormality, begin by assessing the rotational profile. This allows one to measure the severity of the rotational problem. The rotational profile provides the information needed to establish a diagnosis and to quantify the severity of the rotational problem present.

Firstly, inspect the patient standing from the front. When excessive femoral anteversion exists, the patellae face each other medially. Secondly, ask the child to walk towards you and estimate the foot-progression angle (FPA)—the angular difference between the long axis of the foot and the line of progression. Intoeing is denoted by a minus sign and out-toeing by a plus sign. In a normal child, the FPA is +10° with a range from -3 to +20°. Thirdly, examine the child prone with the knees flexed 90°. To determine the amount of hip rotation, allow both hips to fall into maximum internal and external rotation. The legs should be allowed to fall by gravity alone—do not use force. The amount of internal and external rotation of the hip should normally be similar and the total arc should be about 90°. Medial rotation more than 70° suggests a diagnosis of excessive femoral anteversion. It is considered mild if the degree of internal rotation is 70 to 80° and the external rotation is 10 to 20°; moderate if internal rotation is 80 to 90° and lateral rotation is 0 to 10°; and severe if the internal rotation of the hip is greater than 90° with no external rotation (Fig 1).

To determine the degree of tibial rotation, the thigh-foot angle or the transmalleolar angle needs to be estimated. The thigh-foot angle is the angular difference between the axis of the foot and the axis of the thigh when the patient is in the prone position with the knees flexed 90° and the foot and ankle in neutral position. A negative value is given when the tibia is rotated internally (internal tibial torsion) and a positive value given when the tibia is rotated externally (external tibial torsion). In the infant, the thigh-foot angle is internal (negative) but it becomes progressively external (positive) with increasing age. During childhood, the mean thigh-foot angle is +10° with a range

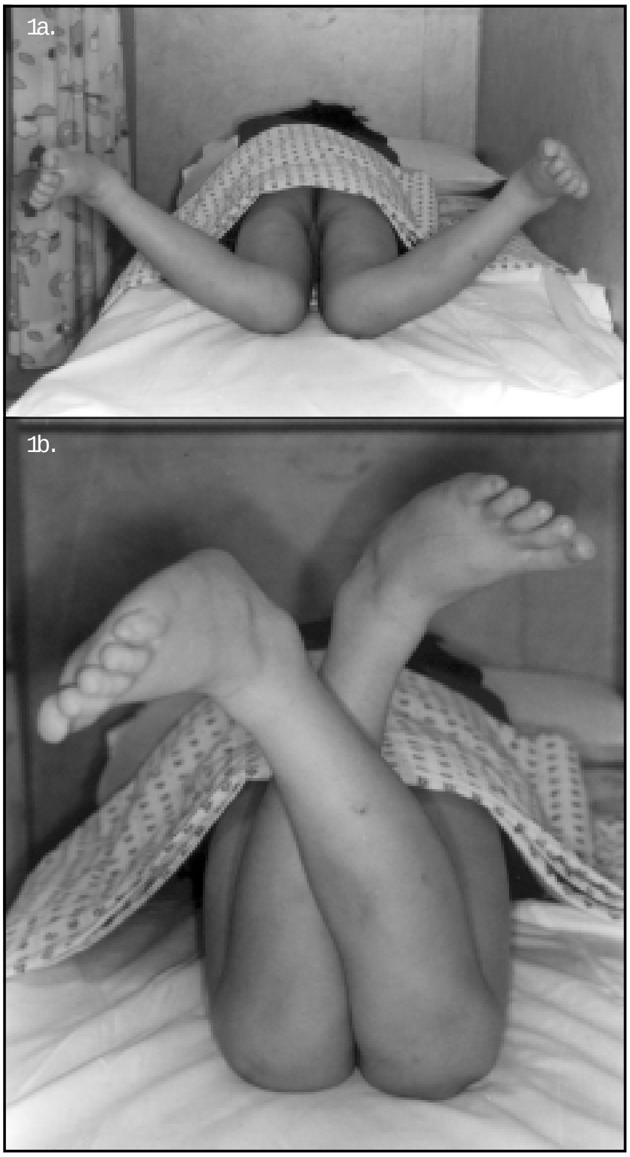

Fig 1. Hip rotation in the prone position in a patient with excessive femoral anteversion
Normally, the internal and external rotation angles are more or less the same (40-50°). In this patient, there is (1a) an increase in internal rotation to 70° and (1b) a decrease in external rotation to 20°

of -5 to +30° (Fig 2). If the foot is deformed, the thigh-foot angle cannot be used. Instead, the transmalleolar axis-thigh angle is used. The transmalleolar axis is a line across the sole of the foot connecting the centers of the medial and lateral malleoli. A right angle to this line is compared with the axis of the thigh to provide the angle.

Finally, the shape and direction of the sole of the foot should be determined. The deformity can be assessed by projecting the bisector line of the heel to the forefoot to quantitate forefoot adduction. In the normal foot, this line projects between the second and third toes. In metatarsus adductus or in clubfoot, the line projects toward the lateral toes.

Fig 2. A negative thigh-foot angle in a patient with internal tibial torsion
The normal angle is about +10 to +15°. In this patient, the angle is -20°

Imaging techniques used

A physical examination usually provides sufficient information to formulate a treatment plan and further imaging is usually not required. There are, however, a number of imaging methods that can assess the amount of torsional deformity present in the bone. Imaging may need to be used in patients with hip dysplasia or cerebral palsy, or when significant rotational deformity does not resolve and corrective surgery is needed.

Plain X-ray

On an anteroposterior pelvis X-ray, an apparent coxa valgus is shown due to femoral anteversion. To measure the femoral anteversion, many radiographic techniques have been reported but most require the use of special positioning techniques or conversion tables[9] and so are not useful in clinical practice. The main purpose of taking a plain X-ray in these patients is to rule out hip dysplasia. Radiographs of the tibia are not helpful in assessing tibial torsion.

Fluoroscopy

Fluoroscopy can help to quantitate the degree of femoral anteversion. The hip is rotated under fluoroscopy until a true AP view of the hip is obtained. The amount of internal rotation of the leg in that position is the femoral anteversion.[10]

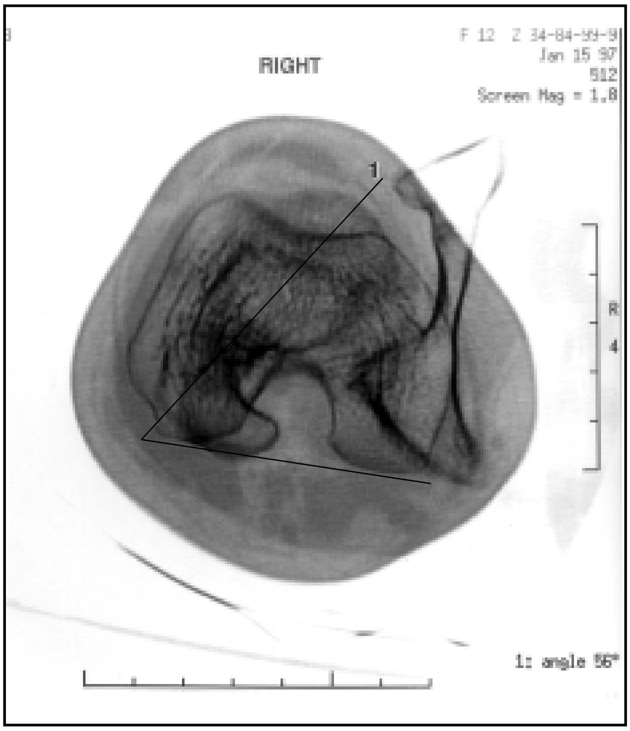

Fig 3. Computed tomography scan showing the femoral neck and the bicondylar axis of the distal femur overlapping each other
Excessive femoral anteversion is present and measures 56° (normal adult value is approximately 15°)

Computed tomography

Computed tomography is the best imaging technique for evaluating femoral anteversion. It should only be used, however, when diagnosing a complex hip deformity or when a rotational osteotomy is being contemplated. The angle formed by the bicondylar axis and a line up the femoral neck represents the amount of femoral anteversion (Fig 3).[11,12] Although CT scanning can be used to make a tibial rotation assessment, clinical evaluation is generally sufficient.

Ultrasonography

Ultrasonography can be used to measure the amount of femoral or tibial torsion but this method is known to not be as accurate as using a CT scan.[13,14]

Metatarsus adductus

In a child with metatarsus adductus (sometimes called metatarsus varus), the forefoot is adducted and the lateral border of the foot is convex. The medial border is concave and a deep crease may be present. Normally, a line bisecting the heel should traverse the space between the second and third toes. In patients with metatarsus adductus, the line will be directed to the lateral toes. This deformity is differentiated from clubfoot in that the heel is not in an equinovarus position.

When evaluating the foot, the flexibility must be assessed. The deformity can be classified depending on the flexibility on passive correction. The foot is considered normal if the heel bisector line passes between the second and third toes. The deformity is classified as mild, moderate, or severe if the bisector passes through the third toe, the third and fourth web space, or the fourth and fifth web space, respectively.[15]

Most children who have metatarsus adductus at birth do not require treatment. If the child has a moderate or severe deformity that is not passively correctable, casting or manipulation and taping is needed. It is prudent to wait until the child is older than 6 months before beginning casting or manipulation and taping because many feet correct spontaneously. Surgical treatment is only needed in the few cases of rigid and severe deformity that do not respond to conservative treatment. The usual indications are residual metatarsus adductus in a child older than 3 to 4 years. Extensive tarsometatarsal capsulotomies[16] are done on the younger child, and multiple metatarsal osteotomies are performed on the older child.

Internal tibial torsion

Children with internal tibial torsion walk with a pigeon-toed or intoed gait. This is most common in children between the ages of 1 and 2 years. Involvement is often bilateral; in unilateral cases, the left side is more often involved. When the patellae are facing straight forward, the feet point inward. In the prone position, the thigh-foot angle is negative.

The natural course of internal tibial torsion is spontaneous correction with growth.[17] The affected child may trip and fall more easily but spontaneous resolution is rapid in early childhood and there should be no residual disability. Clinical studies suggest that non-operative treatment of tibial torsion is ineffective.[18-20] Consequently, any treatment of tibial torsion in the infant or child is both unnecessary and may even be harmful.

Excessive femoral anteversion

Excessive femoral anteversion usually presents as a cause of intoeing at 3 to 4 years of age. It is present at birth but is masked by the lateral rotation contracture of the hip. Intoeing due to excessive femoral anteversion increases up to 5 to 6 years of age and then gradually decreases. It is more common in females, is familial, and is often symmetrical. When the child is standing, the patellae and knees are turned inward the child prefers to sit in the 'W' or reversed tailor position. The FPA is negative and the child may trip and fall easily because of crossing over of the feet. When the patient is in the prone position, there is excessive internal rotation of the hips (as much as 90°) and restriction of external rotation of the hips (0° in severe cases). As the child gets older, compensatory external rotation of the tibia may develop. This combination of excessive femoral anteversion and external tibial torsion will give rise to a torsional malalignment syndrome causing an increase in the Q angle, patellofemoral joint instability, and anterior knee pain.

There has been speculation that excessive femoral anteversion may cause degenerative arthritis of the hip; however, it has recently been demonstrated that this is not true.[21-24]

Treatment of affected children

The most important job of the physician is to establish a correct diagnosis and to reassure the parents effectively. The management of paediatric intoeing gait is illustrated in the flow chart (Fig 4).

Common misconceptions

Shoes correct intoeing

Shoe modifications, such as heel and sole wedges or medial arch supports, can modify the pattern of shoe wear but do not change the FPA. These minor shoe adjustments do not influence derotation of the femur or tibia.

Intoeing causes secondary deformities of the spine, hip, and knee

There is no evidence that intoeing can cause osteoarthritis or back pain.[7,8,21-23] Because runners often demonstrate intoeing, some claim that a mild degree of intoeing may actually be beneficial. It is possible that mild intoeing facilitates running by placing the toes in an optimal position to assist in ankle push-off.[24]

Night splints can correct tibial and femoral torsional deformities

Night splints are not useful in remedying excessive femoral anteversion. For internal tibial torsion, some clinicians claim success in using the Dennis-Brown splint but there has been no scientific proof of its usefulness. In the rabbit tibial model, lateral rotation forces have been shown to lead to angulation of the cells within the zone of hypertrophy of the physis, but no cortical remodelling occurs.[25] In a similar rabbit model, lateral rotation splinting changes the static foot angle but does not change bone rotation, which indicates that the 'correction' achieved occurs primarily through the ankle joint, thus potentially damaging the ankle joint.[25]

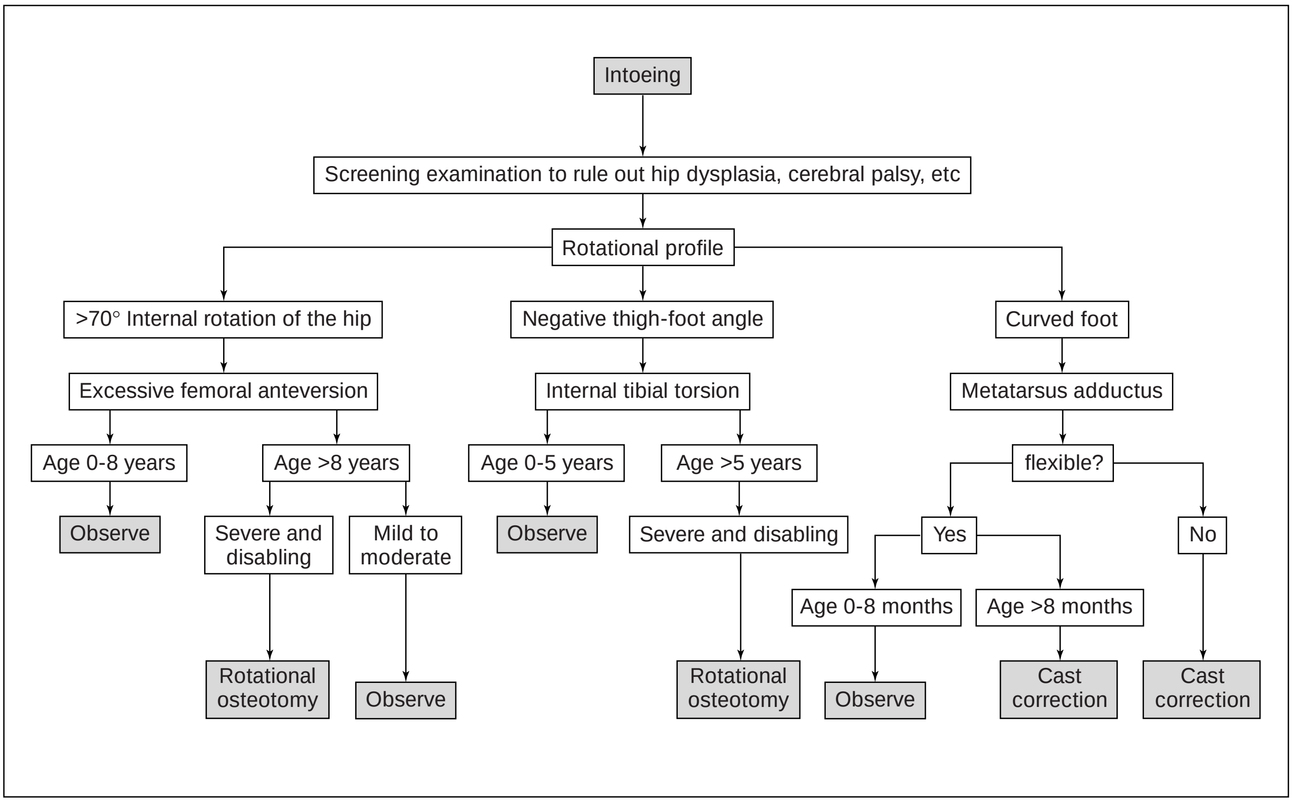

Fig 4. Management flow chart to be followed when treating a child with an intoeing gait

Non-surgical treatment

A careful evaluation of the child is essential and after ruling out serious pathology, an effort must be made to establish what concerns the parents have. The natural course of intoeing should be outlined and the common misconceptions surrounding intoeing explained. Reassurance should be given that the child will be followed up regularly and carefully.

Intoeing due to excessive femoral anteversion and internal tibial torsion should not be treated with night splints, twister cables, orthotics, or special shoes. These methods will not alter the natural course of these conditions.

Surgical treatment

Derotation osteotomy is the surgical treatment of choice for children with severe and persistent rotational problems. An adequate number of years must pass to make sure that the rotational deformities will not resolve naturally (Fig 4). Surgery should not be performed for a very young child. In general, tibial derotation osteotomy is seldom needed before age 5 years, and femoral derotation osteotomy should not be done before 8 years.

Patients with cerebral palsy more often have excessive femoral anteversion than do normal children and their anteversion seldom improves with time. It may be appropriate to perform surgery in these patients at an earlier age. A tibial derotation osteotomy can be performed proximally or distally; however, there are fewer complications with the distal osteotomy.[26]

Femoral derotation osteotomy can be performed anywhere along the rotated femur. In children younger than 10 years, femoral osteotomy is most easily achieved by a distal osteotomy stabilised by pin or staple fixation with a long leg plaster cast in place for 6 to 8 weeks.[27] Proximal intertrochanteric or subtrochanteric osteotomy with blade-plate fixation is advocated by some to avoid cast immobilisation in the older child and teenager (Fig 5).[28] An alternative is closed femoral derotation osteotomy and femoral intramedullary nailing, which allows the quickest return to weight-bearing walking without the use of a cast.[29]

Fig 5. Derotation osteotomy at proximal femur is fixed with a dynamic hip screw in a patient with unresolved excessive femoral anteversion

Conclusion

Intoeing is common in infants and children. The condition causes concern in parents and sometimes produces minor functional problems in children such as frequent tripping. The parents' concerns must be taken seriously. The child must be evaluated carefully and an accurate diagnosis made. Giving reassurance to the parents is important. Most patients can be treated by observation alone and osteotomy is needed only rarely in the occasional patient with severe deformities that do not resolve with time.

References

1. Eckhoff DG, Winter WG. Symposium on femoral and tibial torsion [editorial]. Clin Orthop Rel Res 1994;302:2-3.
2. Guidera KJ, Ganey TM, Keneally CR, Ogden JA. The embryology of low-extremity torsion. Clin Orthop Rel Res 1994;302: 17-21.
3. Staheli LT. Torsional deformity. Pediatr Clin North Am 1977;24:799-811.
4. Staheli LT, Corbett M, Wyss C, King H. Lower extremity rotational problems in children. Normal values to guide management. J Bone Joint Surg 1985;67A:39.
5. Fabry G, MacEwen GD, Shands AR Jr. Torsion of the femur: a follow-up study in normal and abnormal conditions. J Bone Joint Surg 1973;53A:1726-38.
6. Badelon O, Bensahel H, Folinais D, Lassale B. Tibiofibular torsion from the fetal period until birth. J Pediatr Orthop 1989; 9:169-73.
7. Eckhoff DG, Kramer RC, Alongi CA. Femoral anteversion and arthritis of the knee. J Pediatr Orthop 1994;14:608-10.
8. Terjesen T, Benum P, Anda S, Svenningsen S. Increased femoral anteversion and osteoarthritis of the hip joint. Acta Orthop Scand 1982;53:571-5.
9. Kane TJ, Henry G, Furry DL. A simple roentgenographic measurement of femoral anteversion. J Bone Joint Surg 1992;74A:1540-2.
10. Rogers SP. A method for determining the angle of torsion of the neck of the femur. J Bone Joint Surg 1931;13A: 821-4.
11. Weiner DS, Cook AJ, Hoyt WA Jr, Oravec CE. Computed tomography in the measurement of femoral anteversion. Orthopedics 1978;1:299-306.
12. Fabry G, Cheng LX, Molenaers G. Normal and abnormal torsional development in children. Clin Orthop Rel Res 1994; 302:22-6.
13. Phillips HO, Greene WB, Guilford W, et al. Measurement of

femoral torsion: comparison of standard roentgenographic techniques with ultrasound. J Pediatr Orthop 1985;5:546-9.
14. Joseph B, Carver RA, Bell MJ, et al. Measurement of tibial torsion by ultrasound. J Pediatr Orthop, 1987;7:317-23.
15. Bleck EE. Metatarsus adductus: classification and relationship to outcomes of treatment. J Pediatr Orthop 1983;3:2-9.
16. Heyman CH, Herndon CH, Strong JM. Mobilization of the tarsometatarsal and intermetatarsal joints for the correction of resistant adduction of the fore gait of the foot in congenital clubfoot or congenital metatarsus varus. J Bone Joint Surg 1958;40A:299-309.
17. Weseley MS, Barenfeld PA, Eisenstein AL. Thoughts on in-toeing: twenty years' experience with over 5000 cases and a review of the literature. Foot Ankle 1981;2:49-57.
18. Barlow DW, Staheli LT. Effects of lateral rotation splinting on lower extremity bone growth: an in-vivo study in rabbits. J Pediatr Orthop 1991;11:583-7.
19. Heinrich SD, Sharps C. Lower extremity torsional deformities in children: a prospective comparison of two treatment modalities. Orthop Trans 1989;13:554-5.
20. Knittel G, Staheli LT. The effectiveness of shoe modifications for intoeing. Orthop Clin North Am 1976;7:1019-25.
21. Hubbard DD, Staheli LT, Chew DE, Mosca VS. Medial femoral Torsion and osteoarthritis. J Pediatr Orthop 1988; 8:540-2.
22. Kitaoka HB, Weiner DS, Cook AJ et al. Relationship between femoral anteversion and osteoarthritis of the hip. J Pediatr Orthop 1989;9:396-404.
23. Wedge JH, Munkacsi I, Loback D. Anteversion of the femur and idiopathic osteoarthrosis of the hip. J Bone Joint Surg 1989; 71A:1040-3.
24. Fuchs R, Staheli LT. Sprinting and intoeing. J Pediatr Orthop 1966;16:489-91.
25. Moreland MS. Morphological effects of torsion applied to growing bone: an in-vivo study in rabbits. J Bone Joint Surg 1980;62B:230-7.
26. Krengel WF, Staheli LT. Tibial rotational osteotomy for idiopathic torsion: a comparison of the proximal and distal osteotomy levels. Clin Orthop Rel Res 1992;283:285-9.
27. Hoffer MM, Peitetto C, Koffman M. Supracondylar derotational osteotomy of the femur for internal rotation of the thigh in the cerebral palsied child. J Bone Joint Surg 1981;63: 389-93.
28. Payne LZ, DeLuca PA. Intertrochanteric versus supracondylar osteotomy for severe femoral anteversion. J Pediatr Orthop 1994;14:39-44.
29. Winquist RA. Closed intramedullary osteotomies of the femur. Clin Orthop Rel Res 1986;212:155-64.