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Torsional Deformity: A Review Article

Pande Putu Agung Willa Kesawa Putra[1], Made Agus Maharjana[2]

[1]Resident of Orthopedic and Traumatology Department, Faculty of Medicine,
Udayana University/Prof. Dr. I.G.N.G. Ngoerah General Hospital, Denpasar, Bali, Indonesia
[2]Consultant of Orthopaedic and Traumatology Department, Faculty of Medicine,
Udayana University/Prof. Dr. I.G.N.G. Ngoerah General Hospital, Denpasar, Bali, Indonesia

Corresponding Author: Pande Putu Agung Willa Kesawa Putra

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ABSTRACT

Rotational variations of the lower extremities, including in-toeing and out-toeing, are common in children and usually represent normal developmental differences rather than pathological conditions. In-toeing is most frequently caused by metatarsus adductus in infants, internal tibial torsion in toddlers, and persistent femoral anteversion in older children, while out-toeing may result from femoral retroversion, external tibial torsion, severe pronation, or torsional malalignment. Diagnosis relies on history and physical examination, including assessment of Foot-Progression Angle (FPA), hip rotation, tibial torsion, and the transmalleolar axis, with imaging reserved for atypical or severe cases. Management is predominantly non-surgical, focusing on observation and physiotherapy, with most children improving spontaneously over time. Surgical intervention, such as rotational osteotomy, is indicated in absolute cases with severe functional or cosmetic impairment. Understanding the natural history, diagnostic evaluation, and treatment options is essential for guiding clinical management and counseling families.

Keywords: Torsional Deformity, In-toeing, Out-toeing

INTRODUCTION

Rotational profiles in children vary widely and are often considered normal variations rather than pathological conditions. Foot position during gait is described relative to the line of progression of the body during the step cycle and may present as internal, external, or neutral rotation. Torsion refers to a deformity involving rotation along the longitudinal axis, where one end of the structure is considered stable while the other rotates. In the femur, the torsional angle is measured between the distal intercondylar axis and the proximal femoral neck axis. A positive angle, when the femoral neck axis is oriented anteriorly, is termed antetorsion (anteversion), whereas a negative angle, when oriented posteriorly, is termed retrotorsion (retroversion).[1]

Version, although less frequently used, can be considered similar to torsion. It generally refers to alignment within the normal range, while torsion describes alignment beyond the normal range. Femoral anteversion can be evaluated using imaging modalities such as MRI or CT scan. Clinically, these rotational variations often manifest as in-toeing or out-toeing. Epidemiologically, in-toeing is far more common, affecting up to 13.6% of children, with nearly all cases presenting as in-toeing (≈97%), while out-toeing is rare (≈3%) and reported in only 1–2% of torsional anomalies. [1]

CLINICAL TYPES OF TORSIONAL DEFORMITY

IN TOEING

Metatarsus Adductus

Metatarsus adductus commonly causes in-toeing in infants under one, affecting 1 in 1000 births equally in males and females. [2] Risk factors include primigravida, advanced maternal age, and multiple gestations. [3,4]

It is defined as medial deviation of the forefoot at the tarsometatarsal joint, which may be flexible, semi-flexible, or rigid depending on the degree of passive abduction possible. Assessment of severity and flexibility can be performed using the heel bisector angle. [3,4]

Tibial torsion

Internal tibial torsion is the simplest of the three conditions. It is characterized by internal rotation of the tibia and is the most common cause of in-toeing in children aged 1–3 years. The condition is often bilateral and usually resolves by the age of six. Infants typically have an average internal rotation of 5° (range: −30° to +20°), whereas children aged eight years and older usually have an average external rotation of 10° (range: −5° to +30°). [4,5]

Femoral Anteversion

Femoral anteversion is most often diagnosed between the ages of 3 and 6 years. Later presentation is mainly due to overlap with physiological external hip contracture. Femoral version refers to the angular orientation between the axis of the femoral neck and the transcondylar axis of the distal femur. At birth, physiologic femoral anteversion is approximately 30–40°, and it progressively decreases with growth, reaching an average value of about 15° at skeletal maturity. Femoral anteversion leads to an increase in hip internal rotation, clinically manifested by medially oriented patellae and a characteristic “egg-beater” pattern during running. Recent studies suggest a genetic predisposition, as the condition tends to run in families and occurs twice as often in girls compared to boys. [4,5]

OUT TOEING

Proximal Femoral Retroversion

When hip external rotation markedly exceeds internal rotation, the lower limb rotates outward even if the foot is aligned. Unlike anteversion, femoral retroversion rarely corrects with growth and may cause abnormal gait, limited sports activity, and hip pain progressing to early osteoarthritis. Surgery may be required as early as 3–4 years when function is impaired, or later if recurrent pain develops. [1]

Reduced version includes: (1) diminished femoral anteversion into the neutral range or absent torsion, and (2) true retroversion, with the femoral head–neck axis displaced posteriorly below the transverse plane. CT scan is essential before surgery. Correction uses femoral internal rotation osteotomy at various levels, requiring precise technique to avoid secondary deformities. [1]

External Tibial Torsion

The distal tibia may rotate abnormally even when femoral rotation is within the normal range. External tibial torsion is a condition where the ankle joint points outward and causes flatfoot, pronation, and eversion. External tibial torsion tends not to correct with growth but does not require osteotomy. The decision for surgery is usually made around age 10 based on overall functional considerations and associated secondary foot deformities. Correction is performed with a supramalleolar internal rotation osteotomy of the distal tibia and fibula. Foot correction may also be required. [1,4]

Out-Toeing Due to Severe Flatfoot with Eversion and Pronation

Sometimes out-toeing is caused only by severe flatfoot and pronation. Foot orthoses may help. If surgical correction is desired and the hip, knee, and ankle joints are normal, then only the foot needs to be addressed. A Dwyer-type calcaneal osteotomy is utilized to reorient and

medially translate a significantly valgus heel toward a more neutral alignment. In cases of pronounced forefoot abduction, a distal calcaneal lengthening osteotomy may be indicated, as it corrects flatfoot deformity by lengthening the lateral column and thereby realigning the midfoot and forefoot. [1,4]

Torsional Malrotation Syndrome

Foot and ankle may appear normal when standing, but gait is impaired by opposite malrotation of the femur and tibia/fibula at the knee. Mild genu varum can occur, with anterior knee pain from lateral patellar subluxation. In femoral anteversion, correcting thigh position may straighten the knee but worsen foot rotation. Surgical correction requires femoral external rotation osteotomy plus tibial/fibular internal rotation osteotomy for full alignment. [1]

This combined deformity, also called severe torsional malrotation syndrome or Judet's triple deformity, consists of femoral anteversion, external tibial torsion, and genu varum. It causes awkward gait, abnormal appearance, and retropatellar pain. If unresolved by age 6–8 or symptomatic with pain, surgery is indicated. [1]

NATURAL HISTORY OF ROTATIONAL VARIATIONS

Most children evaluated for in-toeing or out-toeing are normal, with wide variations in hip and tibial rotation, particularly in toddlers under 2 years and many between 2 and 5 years. [6]

Internal tibial torsion is more common than external torsion and often resolves within 1–2 years, though sometimes persisting into preadolescence, whereas external tibial torsion is less common but more likely to persist into adolescence. [6]

Hip rotation contractures from intrauterine positioning gradually resolve by 18–24 months, with femoral anteversion decreasing from about 30° at birth to 20° by age 10. Changes in muscle balance and hip capsular flexibility influence gait more than femoral anteversion alone. Children with in-toeing or out-toeing but hip rotation within ±2 standard deviations are considered normal. [6,7]

Rotational variations have not been directly linked to degenerative joint disease. Mild anterior knee pain may occur with increased medial femoral rotation but usually without patellofemoral changes. Functional limitations, athletic performance, and risk of slipped epiphysis are generally unaffected by rotational profile. Extreme rotational variations may appear abnormal to parents, yet objective musculoskeletal function is typically preserved. Clear communication with parents is essential before recommending any active interventions, and hip or knee pain should be evaluated for possible osteotomy if symptomatic. [6,7]

EPIDEMIOLOGY

Even though in-toeing is much more common than out-toeing, numerical data are limited. In a study of 1,320 children, gait disturbances due to proximal femoral torsion were observed in 180 children (13.6%), of which 174 cases (96.7%) were in-toeing and only 6 cases (3.3%) were out-toeing, confirmed by hip range-of-motion measurements with the child prone and the hip fully flexed. French studies also highlight the rarity of out-toeing, reporting incidences of 1.1% and 2%. [1]

In infants, in-toeing is usually caused by metatarsus adductus, which often resolves spontaneously or with simple orthopedic management such as exercises, casting, or corrective footwear. [8] Between ages 2 and 6, internal tibial torsion is the main cause, while in children 6–10 years, persistent femoral anteversion predominates. Out-toeing is less common and initially due to hip soft tissue stiffness, later caused by external tibial torsion in younger children and femoral retroversion in older children and adolescents. Both out-toeing deformities rarely improve with growth, and external rotation limitations have greater functional impact than internal rotation. [1]

PATHOPHYSIOLOGY

Abnormalities are defined as secondary external deformities resulting from intrauterine crowding. Intrauterine crowding can occur due to maternal factors, fetal factors, or a combination of both. During the seventh week of gestation, internal rotation of the lower limbs occurs along with external rotation of the hips and femurs. This position directly reflects the posture of the newborn, in which the hips are flexed and externally rotated while the feet are internally rotated. An observational study conducted in 2007 found no significant difference in the incidence of rotational deformities between infants born in cephalic or breech presentations. [5]

DIAGNOSIS

INITIAL ASSESSMENT

Initial assessment focuses on patella and knee position. Inward-facing patella often indicates proximal femoral anteversion, causing internal rotation of the distal femur, patella/knee, and foot-ankle, which results in in-toeing. Outward-facing patella, though rare, may suggest proximal femoral retroversion, leading to external rotation and out-toeing. Children with significant internal hip rotation may sit in a "W" or "frog" position for stable support. [9]

Pregnancy, birth history, and developmental milestones help identify neurological or orthopedic causes. Perinatal events or diagnoses such as cerebral palsy or spina bifida can cause asymmetry or increased tone in lower limbs, leading to in-toeing. Other factors include genetic conditions causing joint hyperflexibility. In-toeing present at birth may indicate clubfoot or hip dysplasia, while habits like sitting in a "W" position may worsen the rotational deformity.

Evaluation includes growth and joint range of motion versus age norms. Abnormalities may indicate systemic, endocrine, or orthopedic conditions such as rickets, congenital hip dysplasia, or cerebral palsy, requiring referral or imaging. Rotational profile assessed via FPA, TFA, and femoral torsion helps determine gait contributions; values >2 SD from the mean are abnormal [1,7]

PHYSICAL EXAMINATION

Foot-Progression Angle (FPA)

The FPA is a common clinical assessment used in evaluating in-toeing and out-toeing gait. The cumulative position of the thigh and tibia/fibula influences foot orientation. The angle is measured between the long axis of the foot (from the center of the heel pad to the head of the second metatarsal or the second toe) and the line of forward progression. Assessment involves measuring the angle from six footprints (average of three from each limb) on a surface marked with chalk or water-soluble ink over a set distance, such as 6 meters. Normal values vary widely, though studies show an increase with age. A positive (+) sign indicates an outward angle, and a negative (−) indicates inward. A straight-forward foot is noted as 0°. Staheli et al. reported an average normal value of +10° (range −3° to +20°). Losel et al. documented that 4–5-year-old children had an average outward angle of +2.8°, increasing to +7.3° by age 16. The overall range varied from −8° to +16°. In a study by Seber et al. of 50 healthy adult males (20–35 years), the mean FPA was +13.7° on the right and +13.0° on the left (range +6° to +21°). Davids et al. cited +8° (external) as the normal average [1]

Hip Examination

Hip assessment evaluates anteversion or antetorsion, typically performed on a padded exam table. Two common methods are with the child supine (hip in flexion) or prone (hip in extension). Supine assessment evaluates hip range in flexion; both hips are examined in infants and young children to ensure stability. Flexion is adjusted to relax muscles. Internal hip rotation occurs when the foot points outward, and external rotation when the foot moves inward and beyond midline. Normal internal and external rotation ranges from 45° to 60° in young children. Prone assessment evaluates

hip motion in full extension, reflecting gait posture, with similar rotation principles. [1]

Foot, Ankle, and Foot-Arch Examination

Three common methods assess foot-ankle alignment: prone with knees flexed (Thigh-Foot-Ankle), sitting with knees flexed and ankles neutral, and supine with knees straight and ankles neutral. These positions assess tibial torsion but are less accurate than hip ROM measurements, often requiring CT scan support. Thigh-Foot-Ankle angle measures the static, non-weight-bearing rotational position of the foot relative to the thigh. The patient lies prone with the hip fully extended, knee flexed at the proper angle, and foot aligned. The angle is either visually estimated or measured with a goniometer from the longitudinal axis of the posterior thigh to the midline of the foot sole. Neutral alignment is 0°, external rotation is positive (+), and internal rotation is negative (−). Engel and Staheli reported mean TFA values of +11° in infancy, increasing to +18° by age 14. Average TFA ranges from 5° internal in infants (−30° to +20°) to 10° external by age 8 (−5° to +30°), with minimal change after age 12. [1]

Transmalleolar Axis

The distal tibiofibular alignment is evaluated through palpation of the medial and lateral malleoli. Assessment of foot and ankle position is performed with the child seated in an upright posture, knees flexed at the table edge, feet forward, and ankles neutral. In normal conditions, slight external rotation occurs, and the fibular malleolus is posterior to the tibial malleolus. The transmalleolar axis is then measured relative to the transverse plane, defined by the resting foot position on a vertical board while seated. The examination may also be conducted with the patient in a supine position and the knees maintained in full extension mimicking gait posture. The patella is palpated and stabilized anteriorly within the femoral intercondylar notch, while the other hand palpates the malleoli to evaluate the transmalleolar axis. With the knee in extension, the patella remains centered within the intercondylar notch, providing a reference for the transverse plane reference of the knee, whereas the transmalleolar axis reflects the extent of tibiofibular rotation in relation to this plane.[1]

RADIOLOGICAL EXAMINATION

Initial radiographs are not necessary to distinguish normal lower limb variations from pathological conditions. [10] CT or MRI is indicated if hip rotation is asymmetric or surgical planning is required. Femoral torsion is measured as the angle between the femoral neck axis and a tangential line along the posterior femoral condyles, while tibial torsion is measured between a line along the posterior tibial plateau and a line bisecting the malleoli at the tibial pilon. Angles can be obtained from superimposed axial images at the hip and knee for femoral torsion, and tibial plateau and pilon for tibial torsion, or from separate measurements relative to a horizontal reference. [11]

Physical examination correlates significantly with CT measurements. Soyoung Lee et al. reported Pearson correlation coefficients of 0.62 (right) and 0.55 (left) between internal hip rotation and femoral anteversion, and 0.50 (right) and 0.42 (left) between Thigh-Foot Angle and tibial torsion, all significant ($p<0.01$). CT remains the most accurate method due to the femur's 3D structure, with 3D CT accuracy over 99% and standard CT over 96%. Greater hip joint flexibility is associated with a smaller femoral anteversion angle. [12]

MANAGEMENT

NON-SURGICAL

Rotational variations in children, such as in-toeing or out-toeing, generally require only gradual normalization, with most cases not needing active treatment. Interventions like modified shoes, orthoses, or other devices are largely ineffective and provide no proven benefit, while adding unnecessary cost and reinforcing misconceptions about

abnormality. Exercise or muscle-strengthening activities may help reduce dynamic gait components, though evidence is limited. Physiotherapy referrals can be considered for developmental assessment, functional evaluation, and management of associated conditions such as cerebral palsy, spina bifida, muscular dystrophy, or traumatic brain injury, with individualized programs tailored to severity, age, and family needs. Observation with the expectation of spontaneous improvement is recommended, particularly for in-toeing due to persistent femoral anteversion, which often resolves naturally in early childhood. Parents may encourage cross-legged sitting and gentle hip external rotation exercises, though orthotic devices like corrective shoes, twister cables, or Denis-Brown splints are now considered ineffective, and surgical intervention is rarely needed. Spontaneous improvement of femoral anteversion is generally not expected after ages 6–8. [1,13]

SURGICAL

Surgical intervention, specifically rotational osteotomy, may be indicated for children with persistent rotational deformities into childhood or adolescence when gait appearance or function is unacceptable. Postoperative outcomes often include improved appearance, with variable functional benefits; in-toeing patients may fall less frequently, while out-toeing patients may experience better running ability. Pain, though uncommon, can improve, particularly in cases of severe malalignment or combined femoral internal and tibial external rotation, which increases the risk of patellofemoral arthritis. [7]

Preferred techniques for tibial/fibular deformities include supramalleolar tibial osteotomy, sometimes with fibular osteotomy, performed 2–3 cm above the physis and perpendicular to the tibial axis. Deformities >30° may require fibular osteotomy to allow proper rotation. Femoral rotational deformities are corrected by equalizing internal and external rotation, with osteotomy performed proximally, distally, or midshaft depending on associated angular deformities and fixation method. Fixation varies by age and size, including K-wires with casting for younger children, T-plates or clover plates for older children, and intramedullary fixation for patients ≥9 years. Combined femoral and tibial osteotomies may be necessary for symptomatic malrotation, with staged unilateral procedures used for bilateral deformities. [5]

Absolute surgical indications include increased proximal femoral anteversion with absent hip external rotation, proximal femoral retroversion with severely limited internal rotation causing functional out-toeing, and torsional malalignment syndrome combining severe hip internal rotation and tibial/fibular external rotation, often requiring a two-level osteotomy in a single session. [1]

Relative surgical indications involve failure of spontaneous correction to normal range with significant clinical issues such as frequent falls, pain, or cosmetic concerns, including persistent femoral anteversion (<20° external rotation) or persistent tibial-fibular torsion, though compensatory hip rotation may sometimes make surgery unnecessary. [1]

COMPLICATIONS

Treatment of in-toeing and out-toeing, particularly rotational osteotomy, carries risks such as nonunion, infection, blood loss, joint stiffness, scarring, and anesthesia issues. Distal tibial osteotomy and proper fixation reduce complications, including avascular necrosis of the femoral head. Careful surgical planning and precise technique with close follow-up are essential to ensure proper limb function and detect complications early. [7]

CONCLUSION

Foot rotation in children varies widely, and most in-toeing or out-toeing reflects normal variation rather than pathology. In-toeing includes metatarsus adductus, internal tibial

torsion, and femoral anteversion; out-toeing includes femoral retroversion, external tibial torsion, flatfoot-related deformity, and torsional malalignment. Diagnosis relies on history and physical exam (FPA, hip, foot/ankle, transmalleolar axis), with imaging rarely needed initially. Most cases improve spontaneously; physiotherapy is used for support, while rotational osteotomy is reserved for persistent or severe deformities.

Declaration by Authors

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