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Orthopaedic Complications in Infancy

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ABSTRACT

Orthopaedic complications encountered during infancy include a broad spectrum of positional deformities, congenital anomalies, developmental disorders and neuromuscular conditions affecting the musculoskeletal system. Positional deformities such as intoeing, metatarsus adductus, talipes equinovarus, calcaneovalgus, genu varum, genu valgum and pes planovalgus are commonly observed during early childhood and are often associated with intrauterine positioning or physiological developmental variations. While many of these conditions resolve spontaneously with growth, persistent or progressive deformities may require conservative management orthotic intervention, physiotherapy, serial casting or surgical correction. Developmental dysplasia of the hip remains one of the most important orthopaedic disorders of infancy because early diagnosis and treatment are critical for normal hip development and prevention of long-term disability. In addition, neuromuscular and congenital conditions, such as arthrogryposis multiplex congenita, may result in severe joint contractures, muscle weakness and functional limitations that require multidisciplinary rehabilitation. This review summarises the aetiology, clinical presentation, assessment methods, imaging modalities, treatment approaches and rehabilitation principles of common orthopaedic complications observed in infancy. Emphasis is placed on early recognition, physiotherapy management orthopaedic indications and long-term functional outcomes.

Keywords: Infancy, Orthopaedic complications, Intoeing, Femoral anteversion, Tibial torsion, Metatarsus adductus, Talipes equinovarus, Developmental dysplasia of the hip, Pes planovalgus, Arthrogryposis multiplex congenita, Physiotherapy, Pediatric orthopaedics

Abbreviations: AMC: Arthrogryposis Multiplex Congenita; CNS: Central Nervous System; CT: Computed Tomography; DDH: Developmental Dysplasia of the Hip; HKAFO: Hip Knee Ankle Foot Orthosis; KAFO: Knee Ankle Foot Orthosis; LLD: Leg Length Discrepancy; MRI: Magnetic Resonance Imaging; MTA: Metatarsus Varus or Metatarsus Adductus; PPV: Pes Planovalgus; TEV: Talipes Equinovarus; US: Ultrasonographic; LLD: Leg Length Discrepancy

1. Introduction

Orthopedic problems observed during infancy are classified into two groups. The first group comprises positional problems arising from a restricted intrauterine environment. The second group comprises defects involving true congenital anomalies.

1.1. Intoeing

Torsional deformities of the long bones of the lower extremities may lead to gait abnormalities and joint pain in children. Increased femoral anteversion and excessive internal tibial rotation frequently coexist and are defined as malalignment of the lower extremity[1,2].

In the clinical condition referred to as intoeing, three conditions may be present: femoral anteversion, internal tibial rotation and metatarsus adductus. In many children, this condition resolves spontaneously by the age of 8 years old without treatment and is now considered part of normal development[1]. However, in children with persistent intoeing, serial casting may be applied for metatarsus adductus, whereas rotational osteotomies may be performed for internal tibial torsion and femoral anteversion.

1.2. Femoral Anteversion

The femoral anteversion angle is defined as the angle formed between the two most posterior points of the femoral condyles and the midpoint axis of the femoral neck and shaft. Newborns typically have 25° to 35° of femoral anteversion and 0° of tibial torsion. During the first 5 years of life, femoral version decreases to approximately 16°, while the tibia undergoes external rotation up to 20[1,3]°.

Intoeing observed during infancy, decreased external tibial rotation is most commonly present. However, intoeing observed during childhood is generally associated with increased femoral anteversion and increased soft-tissue tightness (Figure 1).

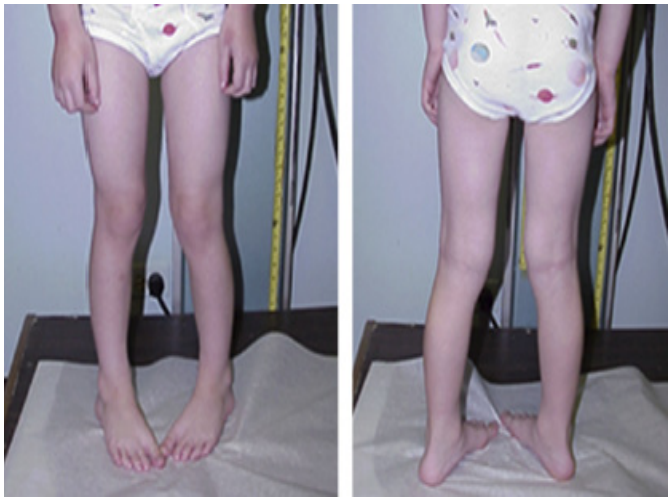

Figure 1: Increased femoral anteversion[4].

In the presence of femoral anteversion, the hip undergoes compensatory in Internal rotation during gait to preserve the lever arm of the hip abductors. During walking, insufficient knee extension mechanics become apparent during the transition from mid-stance to terminal stance. In addition, internal tibial torsion is frequently observed. Children with femoral anteversion commonly prefer the W-sitting position for comfort[5]. However, there is currently no scientific evidence regarding the consequences of this sitting posture (Figure 2).

Figure 2: W-sitting with increased femoral anteversion[5].

To evaluate the femoral anteversion angle, the amount of hip internal rotation is measured[3]. For this assessment, the child is placed in the prone position with the knees flexed to 90°. The greater trochanter is palpated to detect movement and the hip is passively internally rotated. Internal rotation exceeding 45° indicates increased femoral anteversion (Figure 3). During the evaluation, the thigh-foot angle and foot progression angle are also important and should normally range between 5° and 30° (Figure 4). By approximately age 8, the angle is expected to decrease to less than 10°C. In the presence of symptoms such as pain or asymmetry, consultation with an orthopedic specialist is strongly recommended. Surgical indications include severe and persistent tibial or femoral torsion after the age of 8 years, a thigh–foot angle of less than 15° and hip internal rotation greater than 80° after the age of 10 years. Torsional deformities of the femur and tibia can be evaluated using low-dose computed tomography. The functional effects of these deformities can be demonstrated through three-dimensional gait analysis by assessing joint range of motion, joint moments and power generation.

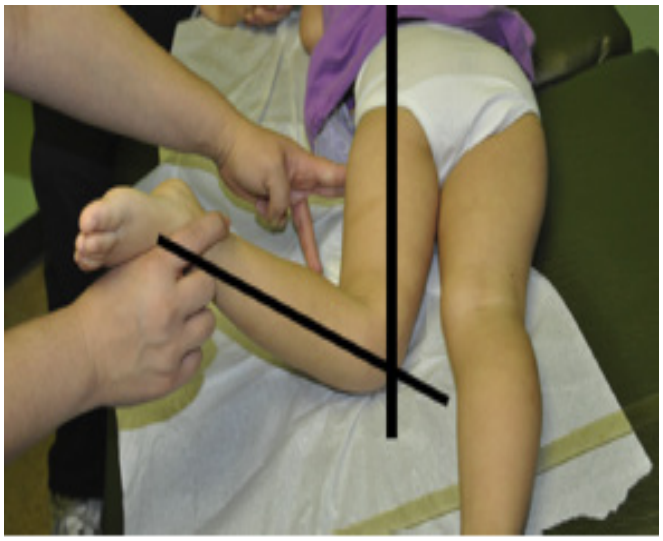

Figure 3: Measurement of femoral anteversion[4].

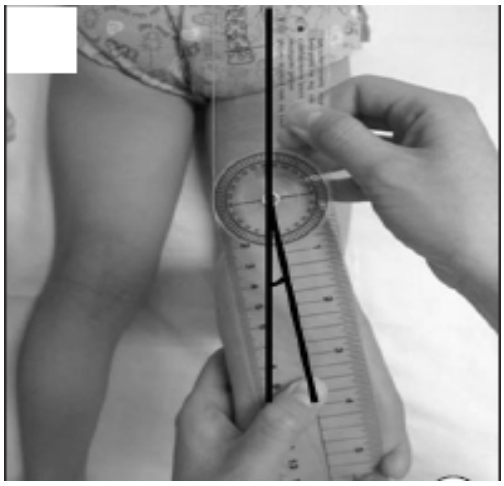

Figure 4: Foot progression angle: The angle between the long axis of the thigh and the long axis of the foot (the axis running from the centre of the heel to the space between the second and third toes)[6].

1.3. Tibial Torsion

Alignment of the lower leg is determined by identifying the hip–foot axis, which is used to define the orientation of the tibia. Tibial torsion is defined as the angle between the two most posterior proximal points of the tibia and the most prominent lateral point of the ankle joint (lateral malleolus)[7]. In essence, lower extremity alignment is determined by the degree of rotation between the proximal and distal ends of the tibia, which represents a structural characteristic of the tibial bone itself (Figure 5). Tibial torsion is commonly evaluated by measuring the angle between the thigh's longitudinal axis and the malleolar axis with a goniometer, while the child is prone with the knees flexed[7] (Figure 6). Some researchers alternatively define tibial torsion as the angle between the axis passing through the knee and the axis connecting the medial and lateral malleoli when both the hip and knee are flexed to 90° (Figure 7). In infants, the tibia is generally internally rotated due to intrauterine positioning. During growth, the long axis naturally derotates. External tibial torsion develops during the first 6 months following the onset of independent walking and continues until approximately 18 months of age[1,7]. At birth, the thigh-foot angle is approximately −15° (normal range: −30° to +20°), whereas at 3 years of age it is approximately +5° (normal range: −10° to +20°). During childhood, normal alignment is characterized by external tibial torsion ranging from 0° to +30°, most commonly around 10°.

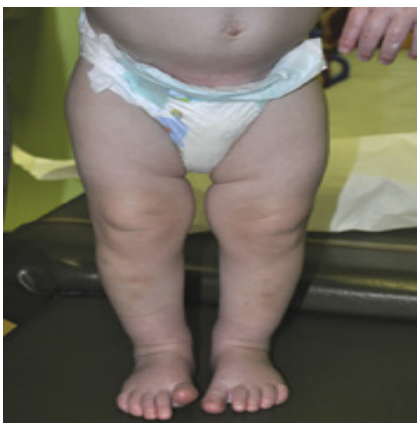

Figure 5: Internal tibial torsion (where the foot's angle of progression is within normal limits but there is external rotation at the knee)[4].

In recent years, studies have also assessed tibial torsion using Computed Tomography (CT), Magnetic Resonance Imaging (MRI) and three-dimensional gait analysis. Goniometric measurements of tibial torsion in children have been reported to range between 0° and 45°.

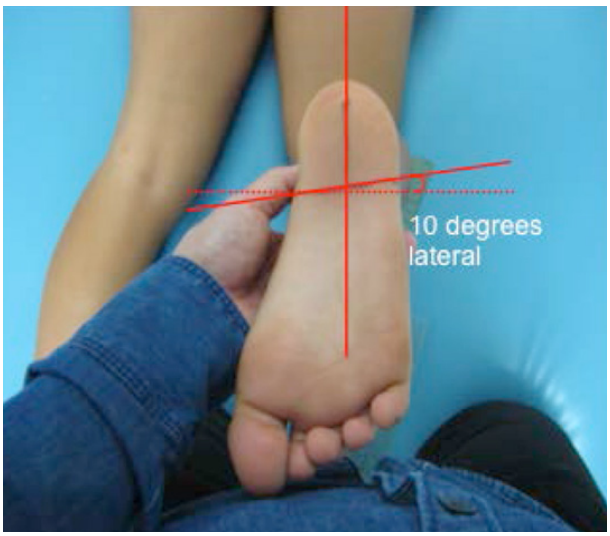

Figure 6: Indirect measurement of tibial torsion using the angle between the malleoli and the long axis of the femur[7].

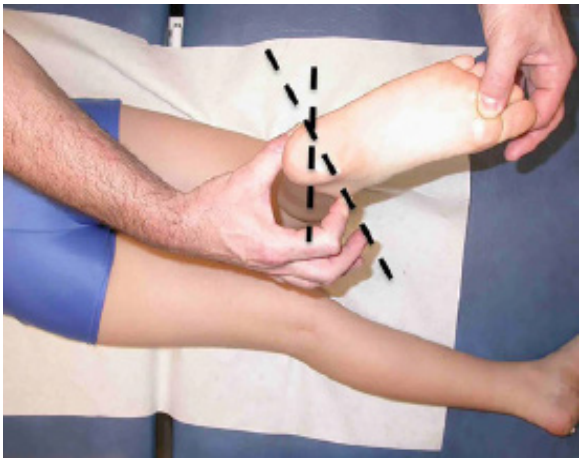

Figure 7: Indirect measurement of tibial torsion using the angle between the malleoli and the long axis of the femur[7].

Infants with internal tibial torsion have shortened extremity rotator muscles in the hip. The infant's lower extremities are positioned in abduction and external rotation. In physiotherapy, treatment options are limited to stretching the hip and lower extremity muscles toward internal rotation and implementing weight-bearing exercises after 6 to 7 months of age; complete correction is generally not achieved. Until approximately 6 months of age, a Denis Browne splint, which maintains the lower extremities in external rotation during sleep, may be used. In later stages, these children may be treated surgically with external rotation osteotomy of the tibia and fibula. In adulthood, increased internal tibial rotation has been associated with knee osteoarthritis and patellar instability. Out-toeing is most commonly caused by excessive external tibial torsion, decreased femoral version or shortening of the hip musculature.

1.4. Metatarsus Adductus

Metatarsus Varus or Metatarsus Adductus (MTA) is one of the most common positional problems in infants, with an incidence of approximately 1-2 per 1,000 live births. It has also been reported to result from a developmental abnormality of the medi-

al cuneiform bone. The deformity is characterized by adduction or medial deviation of the forefoot starting from the tarsometatarsal joint. Associated soft tissue tightness leads to secondary osseous adaptations. Full ankle dorsiflexion range of motion is typically preserved[1]. During clinical assessment, the heel bisection line can be used. With the knee flexed to 90°, a line is drawn from the midpoint of the heel on the plantar surface toward the forefoot and the medial deviation of the forefoot relative to this line is evaluated. Normally, this line passes through the second toe. The condition is classified into three grades: mild, moderate and severe (Figure 8). In mild cases, the line aligns with the third toe; in moderate cases, with the fourth toe; and in severe cases, with the fifth toe. Some clinicians also use Grade 1/2 to describe dynamic MTA, in which the foot appears normal at rest but dynamic forefoot varus and medial deviation of the hallux are observed during gait. Mild cases do not require treatment and typically resolve spontaneously by 4-6 months of age[8]. Moderate cases may respond to stretching exercises and to corrective footwear, such as straight- or reverse-last shoes. Severe cases can be managed with manipulation, serial casting and corrective footwear. However, both mild and moderate forms of MTA generally resolve spontaneously by 3-4 years of age without intervention. Cases that fail to resolve spontaneously may later require surgical correction[9].

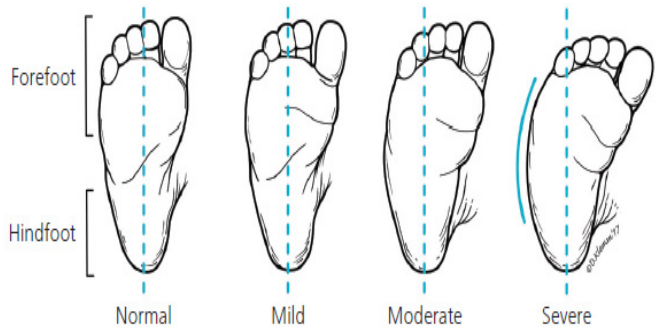

Figure 8: Degrees of metatarsus adduktus[10].

1.4.1. Talipes Equinovarus: Talipes Equinovarus (TEV), also known as clubfoot and often confused with Metatarsus Adductus (MTA), was first described by Hippocrates as medial deviation of the forefoot, a small calcaneus, hindfoot varus and ankle equinus. The foot and calf on the affected side are typically smaller compared to the contralateral side. In some children, TEV may be associated with conditions such as myelomeningocele, developmental dysplasia of the hip and arthrogryposis. The deformity is classically characterized by hindfoot equinus and varus, midfoot cavus and forefoot adduction[11,12]. Typical congenital TEV is thought to result from a combination of genetic predisposition and environmental factors such as abnormal intrauterine constraint, maternal smoking during pregnancy, maternal age, alcohol consumption and oligohydramnios. Approximately 80% of cases are idiopathic and a positive family history is present in about 25% of cases. The incidence is approximately 1 per 1,000 live births, with a male-to-female ratio of 2:1. The most commonly used clinical scoring systems include the Pirani score and the Dimeglio classification, which assess severity based on the physical characteristics of the foot[13]. The primary treatment approach is the conservative Ponseti technique. The Ponseti method consists of two phases:

- **Correction phase:** This includes manipulation, serial casting, bracing and percutaneous Achilles tenotomy. It typically lasts about the first 3 months of life.
- **Maintenance phase:** The foot is maintained in a corrected position using a foot abduction orthosis. The orthosis is initially worn for 23 hours per day during the first 12 weeks and subsequently used as a nighttime splint until 4 to 5 years of age. Functional exercises are initiated once the child begins weight-bearing.

The method is highly effective and surgical intervention is rarely required. Manipulations mainly consist of traction applied in the opposite direction to the deforming forces acting on the foot and typically last about 30 minutes. These include talonavicular joint correction, derotation of the calcaneo-forefoot complex, stretching of the Achilles tendon, lengthening while preserving the midtarsal joint, stretching of the medial arch and plantar fascia and passive mobilization into plantarflexion and dorsiflexion[12,14]. In addition to the Ponseti method, other approaches such as the Robert Debré method, the Saint Vincent de Paul method and the Montpellier method have been described.

If 90° of ankle dorsiflexion cannot be achieved after rehabilitation, a percutaneous Achilles tenotomy is performed. In some cases, additional procedures such as subtalar or tibiotalar capsulotomy or a mini-incision release of the plantar fascia may be required to improve joint flexibility further. Once the child achieves independent and appropriate gait mechanics, physiotherapy sessions are discontinued and the patient is transitioned to a home exercise program with follow-up visits at monthly or 3-month intervals. Night splinting is continued until approximately 4-5 years of age.

1.4.2. Calcaneovalgus: It is a commonly observed positional problem in newborns. In this condition, the forefoot is laterally deviated, the hindfoot is in valgus and excessive ankle dorsiflexion is present. At birth, the dorsum of the foot is in contact with the anterior aspect of the lower leg. Positional calcaneovalgus typically resolves spontaneously without intervention. It should be distinguished from calcaneovalgus secondary to vertical talus. In vertical talus, the talus is positioned vertically and the navicular is displaced dorsally. While the forefoot is dorsiflexed, the hindfoot is in plantarflexion. This condition, referred to as a "rocker-bottom foot" deformity, is typically rigid.

1.4.3. Genu varum: To assess genu varum, the infant is placed in the supine position and the medial malleoli are brought together. One hand is used to stabilize the ankles by keeping the malleoli in contact. The distance between the medial femoral condyles is then measured. The infant's lower extremities should be fully exposed and no diaper should be present during the assessment. In crying or restless infants, a triangular measuring device may be more practical, enabling quicker, more efficient measurements.

Physiological genu varum does not require treatment if it persists beyond 2 years of age or worsens progressively and it typically resolves spontaneously[15] (Figure 9). These infants are generally developmentally normal for motor milestones. In some cases, treatment may involve a Hip Knee Ankle Foot Orthosis (HKAFO) or a Knee-Ankle-Foot Orthosis (KAFO). Surgical intervention is rarely required. If genu varum persists and progresses beyond 4 years of age, the child should be evaluated for systemic disorders, such as vitamin D resistant rickets. Blount disease (also known as idiopathic tibia vara) is another condition characterized by genu varum, resulting from growth suppression of the proximal tibial epiphysis[15]. Medial metaphyseal fragmentation may also be observed in this condition. In infants younger than 3 years with Blount disease,

a rigid HKAFO worn for 23 hours per day is recommended. In some cases, a proximal tibial osteotomy may be required. Genu varum may also be observed in the presence of chondromalacia.

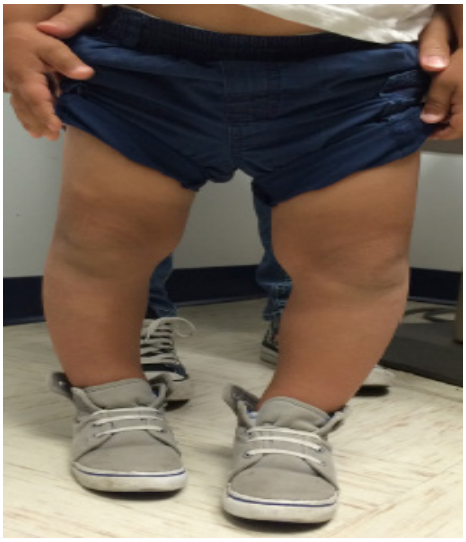

Figure 9: Genu varum[10].

Indications for orthopedic evaluation in genu varum are as follows:

- Positive family history of pathological genu varum
- Asymmetric deformity, including unilateral involvement, gait abnormalities or leg length discrepancy
- Persistent varus deformity at approximately 8 months of age without resolution
- Short stature below the 25th percentile
- Inability to walk after 18 months of age
- Localized Blount's varus angle in the proximal tibia
- Progressive varus deformity persisting beyond 18 months of age
- Persistence of varus alignment beyond 24 months of age

1.4.4. Genu valgum: Like genu varum, genu valgum is not expected to persist beyond 2 years of age. After this age, progressive genu valgum may be observed in overweight children, children with an out-toeing foot progression angle and in cases following fractures or trauma, osteomyelitis and in children with pes planovalgus. The condition is assessed with the infant in either the supine or standing position. During measurement, the medial femoral condyles are brought into contact and the intermalleolar distance is measured. In cases of severe genu valgum or genu varum, guided growth techniques may be applied during adolescence by temporarily tethering the growth plate[16]. This allows continued growth on the untethered side of the femoral physis, resulting in gradual correction and restoration of proper lower limb alignment.

1.4.5. Pes planovalgus: Pes Planovalgus (PPV) is defined as the collapse of the medial longitudinal arch, hindfoot valgus and forefoot abduction and supination. For physiotherapists, PPV is important for achieving proper biomechanical alignment of the lower extremities in infants. In children with flexible pes planovalgus, the medial longitudinal arch appears normal when sitting or standing on tiptoes; however, it collapses when weight is fully applied to the foot[17]. These children are often hypermobile and may demonstrate features of generalized ligamentous laxity, such as the ability to flex the wrist and touch the forearm with the thumb, as well as hyperextension at the knees and elbows. Physiological flatfoot is common in infants and affects approximately 45% of preschool-aged children. In contrast, pathological pes planus is rigid and requires intervention. The medial longitudinal arch typically develops rapidly between 2 and 6 years of age. In painless flexible pes planus, no treatment is required and arch development occurs spontaneously[17,18]. In such cases, there is no indication for footwear modifications, insoles or orthoses. It has been shown that the use of corrective shoes or insoles before age 3 does not affect arch development and these children demonstrate outcomes similar to those of untreated controls. A higher prevalence of pes planovalgus has been reported in children who begin wearing shoes before the age of 6 and in obese children after the age of 6. Shoes supporting the medial longitudinal arch may be recommended; however, they do not facilitate arch formation but may reduce pain by improving biomechanical alignment. In symptomatic flexible flatfoot, conservative management may include rest, activity modification, massage and exercise therapy[17]. Although insoles, shoes or orthoses do not directly promote arch development, they may help reduce pain by improving biomechanical function. In adulthood, a high arch has been reported to cause greater pain and functional impairment than a low arch. Unless associated with other orthopedic or neurological conditions, pes planovalgus is now considered part of normal development in early childhood and no intervention other than lightweight running shoes is generally required. After the age of five, shoes with medial arch support may be recommended to promote proper biomechanical alignment of the lower extremities[19].

Achilles tendon contracture or shortening may lead to secondary pes planovalgus. Examples of conditions associated with this include cerebral palsy, congenital tight heel and muscular dystrophies. Fixed hindfoot valgus may result in pain, callus formation, ulceration and poor tolerance to orthotic devices. These conditions can be corrected with Achilles tendon lengthening procedures and other soft-tissue or bony interventions when necessary.

In cases of Pes Planovalgus (PPV), increased femoral anteversion and external tibial torsion may also be observed concurrently (Figure 10).

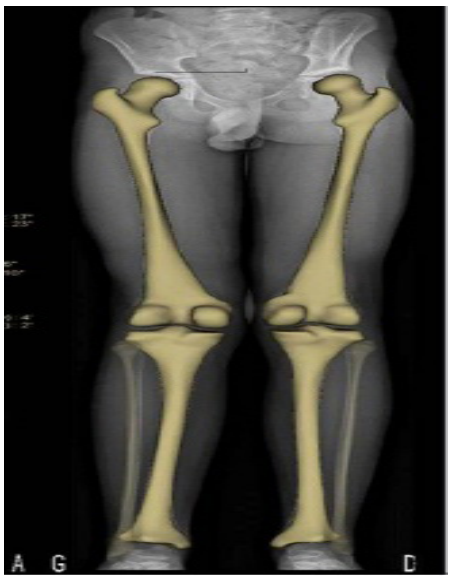

Figure 10: In association with Pes Planovalgus (PPV), increased femoral anteversion and external tibial torsion may also be present[19].

1.4.6. Developmental dysplasia of the hip: Developmental Dysplasia of the Hip (DDH) is synonymous with congenital hip dysplasia and is defined as abnormal development of the femoral head and acetabulum, usually accompanied by joint laxity[20,21]. It has been reported to occur at a rate of 4 per 1,000 live births[22]. In DDH, the acetabular index angle is increased and may progress to subluxation and dislocation over time[20,21]. The acetabular index angle demonstrates the inclination of the acetabulum in the frontal plane. It is the angle between Hilgenreiner's line and a line parallel to the acetabular roof passing through the superolateral edge of the acetabulum[20] (Figure 11).

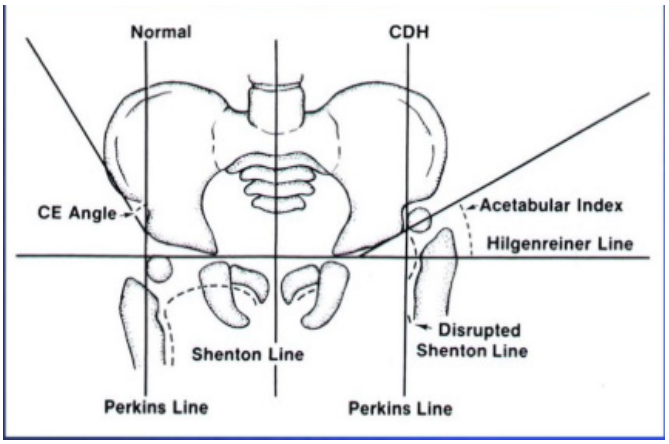

Figure 11: Acetabular index angle[24].

Normal hip development requires normal muscle balance and a femoral head deeply seated within the acetabulum[20,21]. The formation of a concave acetabulum develops through a spherical femoral head. Identification of hip dysplasia during the neonatal period and initiation of treatment are important for normal hip joint development[20,23]. During the early fetal period (6 to 20 weeks), the amount of femoral head coverage and acetabular anteversion does not vary and the hip appears well covered. A fetal dislocated hip becomes apparent only during the last trimester[20]. Predisposing factors for DDH in infants may be classified as mechanical, physiological and environmental factors[20,24]. Mechanical factors include limited intrauterine space and a tight abdominal wall during the first pregnancy, oligohydramnios, breech presentation and positioning of the fetal hip within the mother's sacrum. Physiological factors include maternal hormones such as estrogen and relaxin, which cause ligamentous laxity in female infants. Due to this factor, the female-to-male ratio in DDH is considered to be 6:1. Environmental factors include tightly wrapping the infant's lower extremities in extension by methods such as swaddling after birth[20,24]. Problems associated with DDH include congenital muscular torticollis, metatarsus adductus and calcaneovalgus[21,24].

1.4.7. Assessment: The newborn hip may be classified as follows[20,24]:

- Normal - non-instability
- Subluxatable: The femoral head is within the socket but can partially move out of the acetabulum.
- Dislocatable: The femoral head is reduced but becomes dislocated with the Barlow maneuver.
- Dislocated but reducible: The femoral head is outside the acetabulum at rest but can be reduced with the Ortolani maneuver.
- Dislocated and irreducible: This is rarely encountered after the second month of life. This type of dislocation is mostly teratologic, occurs before birth and is associated with a neurological or muscular anomaly such as myelomeningocele or arthrogryposis[20,21].

During the clinical assessment, hip abduction in flexion is evaluated. Most infants have 75° to 90° of abduction. An asymmetry or limitation of 5° to10° may indicate hip dysplasia[25]. Other clinical findings include asymmetric thigh folds, apparent femoral shortening characterized by inequality of knee levels (Galeazzi sign) and positive Barlow and Ortolani signs[20,24].

The Galeazzi sign is considered positive when one knee remains higher than the other after both hips and knees are flexed to 90°, indicating leg length discrepancy. The dislocated hip remains more posteriorly positioned and the leg appears shorter[20,24].

For the Barlow and Ortolani tests, the infant should be completely relaxed[23,24] (Figure 12). Even the slightest contraction around the hip may mask instability. The findings of these two tests assessing hip instability disappear around 2 to 3 months of age because either hip stability increases and the femoral head settles into the acetabulum or the hip becomes fixed in the dislocated position[20,24]. In the Barlow test, direct posterior pressure is applied to the femoral head from the acetabulum to determine whether it can be displaced out of the acetabulum[23,24]. In infants older than one month, limitation of hip abduction is usually the only finding. During evaluation of hip abduction, the infant lies supine and the pelvis is stabilized while the hips are in 90° flexion. One hip is then abducted. If hip abduction is less than 45°-60° or if there is a 20° difference between the abduction of the two hips, the hip must be examined thoroughly[24,25]. However, it should be remembered that DDH is bilateral in approximately 20% of cases[20].

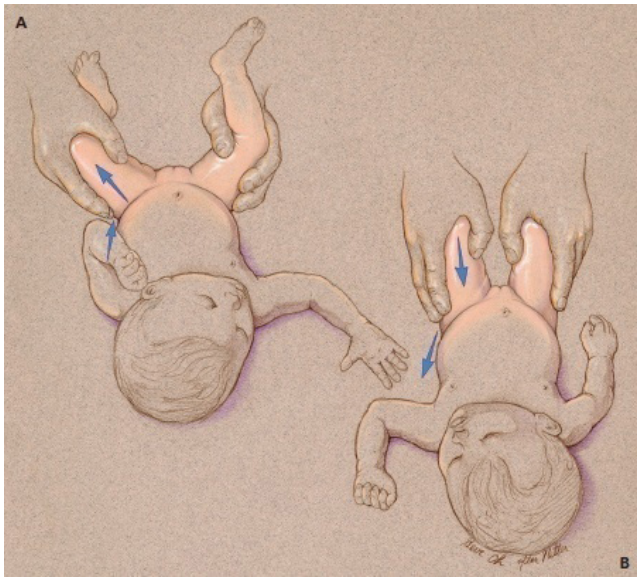

Figure 12: Ortolani Test (A) and Barlow Test (B). In the Ortolani maneuver, the hip flexed to 90° is abducted while anteriorly directed pressure is applied proximally. In the Barlow maneuver, the hips flexed to 90° are adducted while moderate posteriorly directed pressure is applied[24].

Ultrasonographic (US) evaluation of the infant hip is currently very common and is a routine practice[26-28]. US is faster and more useful than other radiographic methods and is used until the age of 3 to 6 months, before the femoral head ossifies and

obscures the visualisation of deeper structures. US enables visualisation of cartilaginous structures that cannot be seen on plain radiographs without radiation exposure and stress tests can also be performed simultaneously[26,27]. In addition to aiding diagnosis, it also demonstrates the extent of progress achieved during treatment[27]. Bilateral dislocations should also be considered in infants. If abduction of both hips is less than 60°, radiographic examination should be performed[24,25]. An acetabular index angle below 30° is considered normal, between 30° to 40° suspicious and above 40° pathological. In older children, especially after 1 year of age, anteroposterior hip radiography is preferred. In this radiograph, the acetabular index angle is considered valuable. It has been stated that the acetabular index angle decreases with age and is used as an assessment parameter for determining hip development[20,21]. According to radiographic findings, the hip is classified as mild radiological deviation, minor joint instability, acetabular dysplasia (without subluxation or dislocation), subluxated or dislocated[20]. Cardiac anomalies, Talipes Equinovarus (TEV) or renal anomalies may accompany the condition[22]. If left untreated, it may lead to damage of the hip joint cartilage and functional loss of movement[20,24].

2. Treatment

2.1. From birth to 6 months of age

The Pavlik harness is a frequently used method for hip reduction in DDH[29,30]. In recent years, treatment protocols have involved monitoring the hip during the first 4 to 6 weeks after birth before initiating Pavlik harness treatment[31]. In 70% to 90% of cases, hip instability resolves spontaneously within 2 to 4 weeks[25,31]. Infants whose hips remain unstable after 4 to 6 weeks of age are treated with a Pavlik harness. The Pavlik harness prevents hip extension and adduction, thereby maintaining the hip in flexion and abduction. The flexion and abduction position supports normal acetabular development and helps facilitate kicking movements. Due to the biological plasticity of the developing bone, positioning the hip in flexion/abduction supports acetabular development[24,30]. The reason for preferring the Pavlik harness is that it allows active hip movement and reduces the risk of avascular necrosis[30,31]. Complications associated with the use of the Pavlik harness include avascular necrosis of the femoral head, femoral nerve palsy, pressure ulcers, musculotendinous shortening, inferior dislocation and erosion of the posterior rim of the acetabulum[24,29]. The Pavlik harness is generally used between the 6th and 12th weeks after birth with ultrasonographic follow-up of the hip. If no improvement in hip development is observed following its use, surgical treatment is indicated[29]. Other orthoses that may be alternatives to the Pavlik harness include the Craig orthosis and the Von Rosen splint[24].

2.2. After 6 months of age

In infants between 6 and 18 months of age diagnosed with a dislocatable or dislocated hip, surgical intervention is generally required. In infants with hip instability after 6 months of age, closed reduction/stabilization under anesthesia is performed. If the procedure is successful, a spica cast (abduction cast) maintaining the hip at 90° to 100° flexion is applied for 6 weeks[32] (Figure 13).

During walking, pelvic obliquity, leg length discrepancy and increased lumbar lordosis are the most prominent findings. A Trendelenburg gait is observed due to weak hip abductors and hip flexion contracture[20,24]. If closed reduction is unsuccessful, open reduction surgery is performed. Open reduction is especially preferred in children older than 18 months[32]. In most cases, a pelvic osteotomy called Salter osteotomy is performed[32,33] (Figure 14). In this technique, an osteotomy is performed on the pelvic bone above the acetabulum. Subsequently, the distal segment is displaced laterally, anteriorly and inferiorly[32]. Following open reduction, a spica cast is also used for 6 weeks, after which physiotherapy is initiated[33]. In particular, if a dysplastic hip with subluxation is left untreated, articular cartilage damage develops in late adolescence. Degenerative arthritis and hip and extremity pain may develop[20,33]. Very mild dysplasia, however, may remain asymptomatic for years and individuals may experience only hip joint degeneration[20].

Figure 13: Spina Cast.

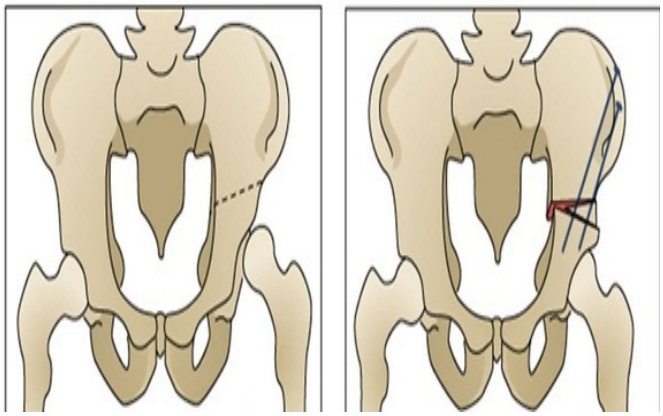

Figure 14: Salter osteotomy[33].

2.2.1. Idiopathic toe walking: Some infants may walk on their toes during the early stages of gait development. This condition may occur even in the absence of a history of prematurity, difficult delivery or hypertonia[34,35]. Interventions that can be applied for infants with "idiopathic toe walking" include:

- Plantar surface, foot and calf massage,
- Normal ankle joint range-of-motion exercises,
- Weight-bearing activities, cruising and gait training on different surfaces while barefoot to promote lower extremity loading (such as sand, sponge, quilt or mat surfaces),

- Use of first-step shoes or orthopedic boots.
- Most infants respond positively to these interventions[35,36].

3. Arthrogryposis Multiplex Congenita (AMC)

Arthrogryposis Multiplex Congenita (AMC) is a non-progressive neuromuscular syndrome[37,38]. The term originates from the Greek words "arthron" and "gryposis," which mean "curved" or "hooked" joints. AMC is characterized by congenitally shortened muscles, non-progressive limitation of joint movements and thickening of the periarticular capsules involving two or more joints[37]. This condition results in severe joint contractures, muscle weakness and fibrosis[20,21,37,38]. Subluxation or dislocation may occur in the hip, knee and patella[20,37]. Long-term outcomes may lead to severe disability and limitations in mobility and activities of daily living[38,39]. The incidence is approximately 1 in every 3,000-4,000 live births, with equal prevalence in male and female infants. In 50% to 60% of cases, all four extremities are affected, whereas 30% to 40% involve only the lower extremities and 10% to 15% involve only the upper extremities[40].

The etiology remains unknown; however, multiple factors during the first trimester of pregnancy are thought to contribute to the condition. Decreased fetal movement is considered a primary cause of multiple joint contractures. Some mothers of infants with AMC report febrile illnesses lasting 1-2 days during pregnancy. Prenatal viral infections, vascular abnormalities between the mother and fetus and uterine septum anomalies are among the suspected etiological factors. Diagnosis may involve muscle biopsy, blood tests and genetic analyses[37].

AMC can be classified into amyoplasia (classic arthrogryposis), distal arthrogryposis, neuromuscular syndromes and Central Nervous System (CNS) arthrogryposis. Amyoplasia is the most common subtype, accounting for approximately three-quarters of all cases[37]. In amyoplasia, clubfoot deformity, elbow extension contracture, shoulder internal rotation and adduction, forearm pronation and hip flexion-external rotation contractures are commonly observed[37,40]. The involvement is generally symmetrical. Distal arthrogryposis primarily affects the hands and feet and demonstrates autosomal dominant inheritance. Neuromuscular AMC is associated with neurogenic and myopathic disorders. Muscle weakness reduces fetal joint movement, leading to joint stiffness and deformities. Muscle imbalance in the extremities causes postural deviations toward the weaker muscles. During the last trimester, decreased amniotic fluid and fetal growth further restrict fetal movements. CNS arthrogryposis results from developmental abnormalities affecting the frontal lobe, such as hydranencephaly and microcephaly[37].

3.1. Clinical findings

Severe joint contractures and deficient muscle development or amyoplasia are commonly observed. Two clinical patterns are most frequently encountered. In the first pattern, the child presents in a flexed posture with hip dislocation, knee extension, equinovarus deformity, shoulder internal rotation, elbow flexion and wrists positioned in flexion with ulnar deviation. In the second pattern, the hips are abducted and externally rotated, the knees flexed and the shoulders internally rotated and adducted, while the elbows remain extended and the wrists flexed with ulnar deviation. Additional findings may include scoliosis, skin dimpling over joints, hemangioma, decreased finger creases, congenital heart defects, facial anomalies, respiratory problems and abdominal hernias[37,40]. It should also be noted that these patients are at risk for scoliosis progression and temporomandibular joint involvement[37,38].

3.2. Medical treatment

The primary component of medical management is appropriately timed surgical intervention. Surgical procedures may include correction of equinovarus deformity, Achilles tendon lengthening, surgical treatment of hip dislocation, surgical treatment of knee flexion contractures and tendon transfers to obtain elbow flexion. When conservative splinting and stretching fail, wrist fusion in a functional position may be performed[40].

3.3. Physiotherapy and rehabilitation

The primary responsibility of the rehabilitation team is to educate the family about AMC[39,40]. Families should be informed that the disease is non-progressive; however, without proper positioning, stretching and strengthening exercises, functional limitations cannot be prevented. Physiotherapy assessment may include goniometric measurements of the joints and motor development evaluations[40]. Motor development is frequently delayed in these infants[38,39]. Infants with AMC commonly present with equinovarus deformity, hip flexion contracture, knee extension contracture, shortening of the internal rotators of the shoulder and elbow and wrist flexion contractures[37,40]. Most of these infants are born in breech presentation[37].

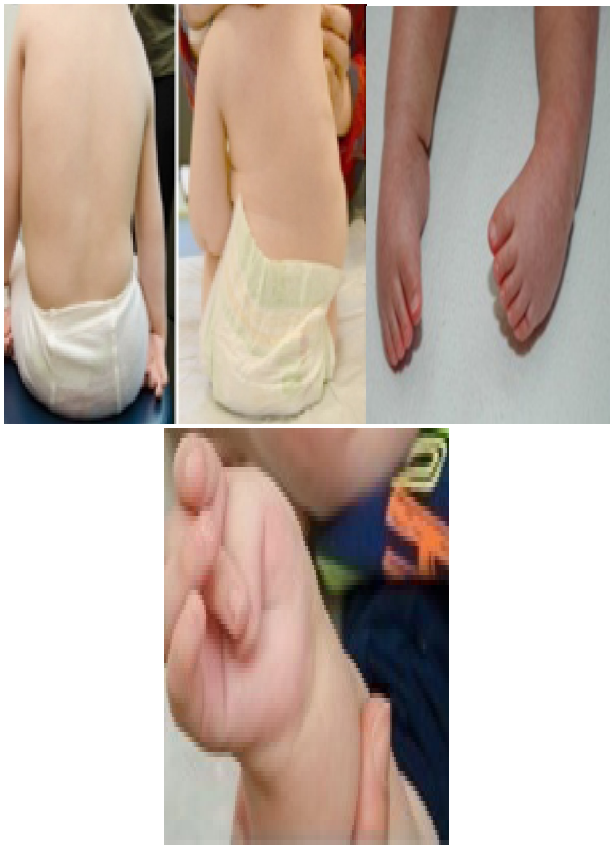

Figure 15: Deformities observed in AMC[38].

The aims of physiotherapy are to increase muscle strength and joint range of motion, support overall sensorimotor development and educate families regarding positioning and stretching techniques. Interventions may include positioning the infant in age-appropriate functional postures, stretching exercises, splinting, gross and fine motor exercises and sensory integration therapy[39,40].

Prone positioning during the first three months is particularly important for preventing hip flexion contractures. These infants often achieve mobility on the floor by moving while sitting on their hips. Surgery for equinovarus deformity should ideally be performed before 2 years of age to allow soft-tissue procedures rather than bony surgery[40]. Most children achieve independent ambulation by approximately two years of age[38,40]. Families should be encouraged to support standing activities beginning at six months of age[40]. For infants who are unable to stand after 18 months, a standing frame may be appropriate[39,40].

Fine motor exercises are important for functional activities such as feeding and should therefore begin as early as possible[39,40]. Stretching exercises should be performed in 3 to 5 sets, with each stretch maintained for 20 to 30 seconds[40]. In children with AMC, stretching exercises are lifelong interventions and regular stretching during the first two years is particularly important[39,40]. Splints should be used to maintain continuity of stretching. The stretching force of splints should not be adjusted to the end range of motion immediately; instead, the stretching intensity should be gradually increased every 4 to 6 weeks[40].

Foot and ankle orthoses should be used for approximately 22 hours per day. Particularly during the first 3 to 4 months after birth, anterior knee flexion splints or posterior knee extension splints should be worn for approximately 20 hours daily. In older infants, knee flexion splints exceeding 50° should be avoided to prevent hip flexion contractures. Knee extension splints may be used after the fourth month during standing activities and sleep. Hand and wrist splints are generally appropriate after the third month, allowing the infant time to develop normal physiological flexion patterns. For daytime use, a neutral-position splint providing gentle extension stretch, placed dorsally and supporting the palmar arches, may be preferred, while a stretching hand-wrist splint may be used at night. Functional hand-wrist splints, maintaining the hand and wrist in an optimal functional position, may also be beneficial during daytime activities[40].

4. Other Orthopedic Problems

4.1. Osteomyelitis

Osteomyelitis is an infection of the bone caused by bacterial organisms. It may spread from the metaphyseal bone to adjacent joints. It can progress rapidly and destructively, leading to permanent complications. It most commonly occurs in the distal femur and proximal tibia. The onset of infection is usually hematogenous and may occur secondary to microorganisms entering the body through the skin, infected wounds or the throat. Symptoms include high fever, pain, tenderness and swelling in the affected metaphyseal region[41,42].

4.2. Septic arthritis

Septic arthritis is an infection of a joint caused by bacteria. It may cause joint degeneration within 48 hours of symptom onset. Permanent gait problems may develop due to cartilage damage. The hip joint is the most commonly affected joint, followed by the knee. In neonates, septic arthritis of the hip is particularly destructive because of complete damage to the cartilaginous femoral head. Even mild cases may lead to permanent complications, as increased intra-articular pressure can result in avascular necrosis. Fever and avoidance of using the affected extremity are commonly observed[43].

4.3. Transient synovitis

Transient synovitis is one of the most common causes of hip pain in children. It is more frequently seen in boys. It may occur secondary to another infection elsewhere in the body and is characterized by joint pain. The condition usually resolves spontaneously within one week[44].

4.4. Occult fracture

Hairline fractures, particularly those referred to in English as “toddler’s fractures,” are examples of occult fractures. The infant may refuse to walk and there may be no obvious history of trauma, fever or signs of infection. Occult fractures are often recognized retrospectively when callus formation begins in the bone. Treatment includes splinting or casting[45].

4.5. Kohler syndrome

Kohler syndrome is an osteochondroses affecting the navicular bone. Pain is present over and around the navicular bone. On radiographic examination, the navicular bone appears sclerotic and reduced in size. The disease generally resolves spontaneously over time[46].

4.6. Achondroplasia

Achondroplasia (dwarfism) is an autosomal dominant disorder within the broad group of osteochondrodysplasias. Characteristics of this disorder include cuboid-shaped vertebral bodies, causing narrowing of the spinal canal, lumbar lordosis, short tubular bones and short hands. Neurological damage associated with spinal anomalies may be observed in 20% to 47% of cases. There are marked differences in the proportions of the extremities and trunk. Hypotonia and transient kyphosis are present in most of these infants[47,48].

4.7. Leg length discrepancy

Leg Length Discrepancy (LLD) is defined as a difference greater than 2.5 cm between the two lower extremities. It may result from traumatic, congenital, neuromuscular, acquired diseases or infections[49]. Treatment may be conservative or surgical. Surgical management includes shortening the longer extremity or lengthening the shorter extremity. Before surgery, physiotherapy interventions include muscle strengthening, passive range-of-motion exercises, sensory training, stabilization exercises and weight-bearing activities on the shorter extremity. In the postoperative period, positioning, splinting, stretching and strengthening exercises are applied. Functional activities, active-assisted and isometric exercises, gait training, bicycle ergometer and treadmill applications are commonly used rehabilitation approaches[50,51].

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