Lower Extremity Deformities in the Developing Child: Physiologic or Pathologic?

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Speaker Introduction

• Carrie Chan currently serves as manager for advanced practice at Stanford Children’s Health and has been a pediatric nurse practitioner with the Stanford Children’s Orthopedic Center and Sports Medicine Program since 2012. She is also involved in teaching as an assistant clinical professor in the pediatric nurse practitioner program at the University of California, San Francisco. She is the co-chair of the NAPNAP Pediatric Orthopedic SIG and secretary on the executive board of the Pediatric Orthopaedic Practitioners Society. Her subspecialty area of clinical and research interest is evaluation and management of spinal deformities.

Disclosures

I hereby certify that, to the best of my knowledge, no aspect of my current personal or professional situation might reasonably be expected to affect significantly my views on the subject on which I am presenting.

Learning Objectives

• Define normal patterns of lower extremity development in children
• Understand physiologic variations of lower extremity rotational and angular profiles in the developing child and the natural history of these presentations
• Identify red flags for pathologic lower extremity deformities and when to refer for specialty evaluation

Intoeing, outtoeing, bow legs, knock knees, W-sitting, funny gait...

Reassurance or referral?

Lower Extremity Development

What is normal?
**“Normal” Development of Lower Extremities**

**Natural History**

- **Genu Varum (Bow Legged)**
  - Birth to 2 yrs
- **Genu Valgum (Knock Kneed)**
  - 2-5 yrs old
- **Adult mechanical axis (“normal”)**
  - 10 – 12 yrs old

**Physiologic Genu Varum (bow legged)**

- Typical from birth to 2 years
- Bilateral and symmetric
- Bowing of femurs and tibias
- Early walkers may have more pronounced varus

**Pathologic Genu Varum**

- Blount’s disease
- Rickets
- Skeletal dysplasia
- Secondary to trauma, infection, neoplasm
**Blount’s Disease – Etiology & Epidemiology**

- Progressive pathologic genu varum
- Multifactorial etiology related to mechanical overload causing disturbance of growth plate
- Risk factors
  - BMI ≥ 85%
  - Early walkers (<1 year)
  - Infantile Blount’s
    - 2-5 years of age
    - Usually bilateral
  - Adolescent Blount’s
    - >10 years of age
    - More likely unilateral

**Blount’s Disease – Evaluation**

- Physical exam
  - Asymmetric varus
  - Focal angulation at the proximal tibia
  - Positive cover-up test
  - Lateral thrust with ambulation
- X-rays
  - Knees pointing straight forward
  - Medial beaking with downward slope of proximal tibial metaphysis

**Blount’s Disease – Management**

- Refer to orthopedics
- Brace treatment if <3 years of age
- Surgical options if >3 years of age

**Rickets – Etiology**

- Metabolic disorder
  - Typically caused by vitamin D deficiency (genetic, nutritional)
  - Deficient bone mineralization
- Risk factors
  - Dark skin
  - Strict diets
  - Exclusively breastfed without vitamin D supplementation
  - Northern latitudes

**Rickets – Evaluation**

- Clinical exam
  - Usually <10th percentile height
  - Bilateral, symmetric bowing of femurs and tibias
  - Possible bowing or widening of other long bones
- X-rays
  - AP and lateral of affected bones
  - Widening and cupping of growth plates
  - Decreased bone density
- Labs

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Rickets – Management

• Medical intervention
  • For most, Vitamin D replacement
  • Referral to endocrine

• Surgical treatment
  • Correct bowing in severe deformity
  • Referral to orthopedics

Skeletal Dysplasia – Etiology & Evaluation

• Multiple forms of skeletal dysplasia associated with genu varum
  • Achondroplasia
  • Pseudoachondroplasia
  • Metaphyseal chondrodysplasia
  • Multiple epiphyseal dysplasia

• Clinical features
  • Short stature
  • Other findings specific to dysplasia type
    • Shortened limbs
    • Frontal bossing
    • Spine abnormalities

Skeletal Dysplasia – Management

• Referral to endocrine, genetics, orthopedics
• Rule out endocrine causes for short stature
• Diagnosis by genetics
• Management of limb deformities by orthopedics

Secondary Causes

• Unilateral bowing caused by damage to growth center from:
  • Fracture/trauma
  • Infection
  • Neoplasm

Secondary Causes – Etiology, Evaluation & Management

• Following growth plate damage from trauma, infection, neoplasm
• Develops within one year of injury
• Clinical exam:
  • Unilateral & asymmetric
• X-ray
  • Narrowing/closure/bar of the affected growth plate
• Management
  • Refer to orthopedics

Bow Legs in Young Children – Normal or Not?

• Clues to pathologic causes of bow-legs:
  • Severe, progressive, or persistent bowing
    • > 6cm between femoral condyles
    • Getting worse, not better after 3 years
  • Unilateral or asymmetric bowing
  • Lateral thrust with ambulation
  • Short stature
  • History of metabolic disease, lower-extremity fracture, infection, or tumor

REFER!
Physiologic Genu Valgum (Knock-knees)
• Typical from 2 to 5 years
• Maximal physiologic valgus by 4 or 5 years
• Bilateral and symmetric
• Normal stature
• Lack of symptoms
• Exaggerated by flat feet

Physiologic Genu Valgum – Management & Education
• Natural history = spontaneous resolution
• Braces, splints, shoe inserts are ineffective

Pathologic Genu Valgum
• Posttraumatic
• Systemic/metabolic conditions
• Skeletal dysplasia
• Neoplasms

Knock Knees in Young Children – Normal or Not?
• Clues to pathologic causes of knock knees:
  • <2 years or >7 years
  • Unilateral valgus
  • Short stature
  • Medial thrust with ambulation
  • Progression rather than improvement after 4 or 5 years of age
  • History of metabolic disease, lower extremity fracture, infection, or tumor

Lower Extremity Development
What is normal?
Where does in-toeing/out-toeing come from?

• Foot alignment
• Tibial rotation
• Femoral rotation

ANY OR ALL OF THE ABOVE!

Physiologic Causes of In-toeing

• Feet: metatarsus adductus
• Tibias: internal tibial torsion
• Femurs: femoral anteversion

Physiologic Causes of In-toeing

• Forefoot adducted
• “Kidney bean” or “C” shape
• Most common cause of in-toeing in infants <1 year
• Bilateral 50% of cases
• Due to intrauterine positioning (“packaging”)
  • More common in late pregnancy, first pregnancy, twin pregnancies, oligohydramnios
  • Associated with hip dysplasia, torticollis
• Up to 3% of newborns

Metatarsus Adductus – Etiology & Epidemiology
Metatarsus Adductus – Evaluation
- Heel bisector lateral to the second toe web space
- Hindfoot neutral
- Ankle and subtalar joint normal range of motion
- Flexibility:
  - Flexible – can be passively abducted past midline
  - Semiflexible – can be passively abducted to midline
  - Rigid – cannot be passively abducted to midline

Metatarsus Adductus – Management
- 90% resolve spontaneously by age 4 years
- Flexible
  - Usually resolve by 1 year
  - No treatment recommended
- Semiflexible
  - Serial stretching
  - Serial casting if not improved by 6 months
- Rigid
  - Serial casting
  - Surgery if fail non-operative treatment and age >5 years

Internal Tibial Torsion – Etiology & Epidemiology
- Internal rotation of the tibia
- Most common cause of in-toeing between 1-4 years
- Bilateral
- Due to intrauterine positioning

Internal Tibial Torsion – Evaluation
- When standing, walking, or sitting, patella points straight ahead and foot points inward
- In prone position, thigh-foot angle is internal

Internal Tibial Torsion – Management
- Generally corrects spontaneously by 5 years
- Bracing not recommended
- Cases that do not completely resolve generally benign
  - Increased incidence in sprinters
- Refer to orthopedics for surgical intervention if unresolved and having functional problems >6-8 years

Femoral Anteversion – Etiology & Epidemiology
- Increased internal rotation & decreased external at the hip
- Commonly seen between 3-6 years
- Bilateral
- Caused by intra-uterine positioning & genetics
Femoral Anteversion – Evaluation
- Prefers W-sitting
- When standing, patella face medially
- When walking, toes and patella point internally
- When running, legs swing out (“egg-beater”)
- Increased internal rotation, decreased external rotation on hip ROM

Femoral Anteversion – Management
- Usually resolves spontaneously by 10 years
- Do not recommend bracing, physical therapy, sitting restrictions
- Even if does not resolve, rarely cause long-term sequelae
- Refer to orthopedics for surgery if functional or cosmetic deformity in child >10

Pathologic Causes of In-toeing
- Clubfoot
- Skewfoot
- Cerebral palsy
- Developmental dysplasia of the hip (DDH)

Clubfoot – Etiology & Epidemiology
- Unclear etiology, genetic component
- Incidence 1:1000
- Half cases are bilateral

Clubfoot – Evaluation
- CAVE deformity
  - Midfoot Cavus
  - Forefoot Adductus
  - Heel Varus
  - Hindfoot Equinus
- Small foot and calf

Clubfoot – Management
- Refer to orthopedics
- Likely serial cast initiation
Skew Foot (Serpentine Foot)

- Z foot
- Forefoot adduction, midfoot abduction, hindfoot valgus
- Limited treatment options:
  - Casting/bracing not effective
  - Surgical correction if symptomatic and functional limitations

Cerebral Palsy – Etiology, Evaluation & Management

- Mild hemiplegic cerebral palsy
- Multifactorial etiology: negative impact on fetal/neonatal brain
  - Prematurity, IUGR, perinatal stroke, infection, etc.
- Presentation
  - Delayed milestones
  - Early hand preference (before 3 years)
  - Asymmetric, unilateral in-toeing gait
  - Posturing of the upper extremity
  - Spasticity/tightness of the affected side
- Management
  - Referral to neurology for evaluation

DDH – Etiology & Epidemiology

- Abnormal development of the hip
- Spectrum of disease
  - Dysplasia (shallow or underdeveloped acetabulum)
  - Subluxation
  - Dislocation
  - Teratologic hip
  - Late (adolescent) dysplasia
- Most common orthopedic disorder in newborns
  - Dysplasia – 1:100
  - Dislocation – 1:1000
  - Female: male ratio 6:1
  - Left hip 60%, bilateral 20%

DDH – Risk Factors

- Four “F”s of DDH
  - Frank breech
  - First born
  - Female
  - Family history

DDH – Infant Evaluation

- Restricted abduction
- Asymmetric thigh folds
- Galeazzi Sign
- Instability with evocative testing
  - Ortolani Maneuver
  - Barlow Maneuver

DDH – Evaluation in an Ambulating Child

- Toe-walking on the affected side
- Persistent increased femoral anteversion on the affected side(s)
- Leg-length discrepancy
- Pelvic obliquity
- Trendelenburg gait
- Limited hip abduction
- Lumbar lordosis
DDH – Evaluation in an Ambulating Child

• X-ray: AP Pelvis

DDH – Management

• Referral to orthopedics
• Likely to require surgery for correction

In-toeing – Normal or Not?

• Clues to pathologic causes of in-toeing:
  • Delayed developmental milestones
  • Recent change
  • Unilateral/asymmetric
  • Pain
  • Limp
  • Functional difficulties

Physiologic Causes of Out-toeing

• Normal intrauterine position: external rotation contracture of the hips
• Tibias: external tibial torsion
• Femurs: femoral retroversion

It starts from the beginning...

• Hips are flexed and externally rotated in utero
• Typically resolves by the time child is walking

Physiologic Causes of Out-toeing

• Normal intrauterine position: external rotation contracture of the hips
• Tibias: external tibial torsion
• Femurs: femoral retroversion
Hip External Rotation (Normal Intrauterine Positioning)
• Positioning in utero results in external rotation of the hips
• Accentuates appearance of genu varum
• Bilateral and symmetric
• When standing, patella and feet point externally
• Typically resolves as child learns to ambulate
• No treatment recommended

External Tibial Torsion – Etiology & Epidemiology
• External rotation of the tibias
• More noticeable late childhood and early adolescence
• Bilateral or unilateral (R>L)

External Tibial Torsion – Examination
• With standing, foot points outward relative to the patella
• External thigh-foot axis

External Tibial Torsion – Management
• Often does not improve spontaneously
• May worsen over time
• Rarely causes pain or functional limitations
• May be associated with “miserable malalignment”
  • External tibial torsion with increased femoral anteversion
  • Knee pain
• Refer to orthopedics if pain or functional problems

Femoral Retroversion – Etiology & Epidemiology
• Excessive external rotation of femurs
• Rare physiologic finding
• Bilateral and symmetric
• External foot and patella progression angles
• Increased hip external rotation vs. internal rotation

Pathologic Causes of Out-toeing
Cerebral palsy
Legg-Calvé-Perthes disease
Slipped capital femoral epiphysis (SCFE)
Cerebral Palsy – Etiology, Evaluation & Management

- Mild hemiplegic cerebral palsy
- Multifactorial etiology: negative impact on fetal/neonatal brain
- Prematurity, IUUGR, perinatal stroke, infection, etc.
- Presentation
  - Delayed milestones
  - Early hand preference (before 3 years)
  - Asymmetric, unilateral in-toeing gait
  - Posturing of the upper extremity
  - Spasticity/tightness of the affected side
- Management
  - Referral to neurology for evaluation

Legg-Calvé-Perthes Disease – Etiology

- Idiopathic avascular necrosis of the proximal femoral epiphysis in children
- Epidemiology:
  - Affects 1:10,000 children
  - 4-8 years old most common age of presentation
  - Male: female ratio 5:1
  - Mostly unilateral involvement

Legg-Calvé-Perthes Disease – Evaluation

- Insidious onset
- May cause painless limp
- Intermittent hip, knee, groin, or thigh pain
- Physical exam:
  - Loss of internal rotation and abduction
  - Antalgic limp, Trendelenburg gait
  - Leg length discrepancy is a late finding
- X-rays: AP/frog pelvis

Stages of Legg-Calvé-Perthes

- Stage 1: Avascular Necrosis
- Stage 2: Fragmentation/Resorption
- Stage 3: Re-ossification

Legg-Calvé-Perthes Disease – Management

- Prognosis:
  - Younger age <6 years at presentation is most important good prognostic indicator
- Refer to orthopedics for care
  - Non-operative
    - Usually for children <8 years
    - Activity restrictions
    - Physical therapy
    - Observation with XR until disease course complete
  - Operative
    - Reserved for children > 8 years
    - Only if have more severe disease course or significant pain
- Slipped Capital Femoral Epiphysis (SCFE) – Etiology

- Disorder of proximal femoral growth plate that leads to slippage of the epiphysis relative to the femoral neck
- Epidemiology:
  - Most common disorder affecting adolescent hips
  - 1 – 2,000
  - Left hip more common
  - teenager 17-50%
  - Average age: 12.3 for girls
  - 13.4 for boys
- Risk factors:
  - Increased BMI
  - Males (3:2 ratio)
  - Puberty
- Associated conditions:
  - Endocrine disorders: workup indicated for child <10 years or weight <50% percentile
SCFE – Evaluation

• History:
  • Groin and thigh pain
  • Most common presentation
  • DO NOT assume groin pull in teenagers
  • Knee pain
    • ALWAYS assess joint above and below pain
    • 23% of the time present with this
  • Duration of pain
    • Present for weeks or months
    • Usually no mechanism of injury
  • Motion
    • Prefers to sit in chair with affected leg crossed over other
    • Hip externally rotated

• Physical Exam:
  • Decreased hip motion
    • Obligatory external rotation during passive flexion of hip
  • Loss of hip internal rotation, abduction, and flexion
  • Abnormal leg alignment
    • Externally rotated foot progression angle
  • Pain in groin, hip, thigh, or knee
  • Abnormal gait
    • Externally rotated gait
    • Trendelenburg gait
  • Weakness

SCFE – Imaging

• Always get AP pelvis AND frog lateral pelvis x-rays
  • Slipped ice cream cone
  • Klein’s Line
    • Good for subtle slips

SCFE – Treatment

• URGENT referral to orthopedics
• Surgery ASAP with in situ fixation
  • Stable SCFE
    • Can wait a day or two, but must NOT walk on it
  • Unstable SCFE
    • Usually admit to hospital, remain NWB and fix ASAP
    • If caught EARLY, relatively minor surgery with good success rates

SCFE – Pearls to Remember

• Adolescent “groin pulls” are SCFEs until proven otherwise
  • Be wary of groin, thigh, and knee pain in adolescents!
  • Careful physical exam is key
  • If any question, get xrays
  • No potentially serious pediatric orthopedic condition that is as easily (and successfully) treated as early SCFEs
    • Treatment of late SCFEs is more difficult, and long-term results are often much worse

Out-toeing – Normal or Not?

• Clues to pathologic causes of out-toeing:
  • Delayed developmental milestones
  • Recent change
  • Unilateral/asymmetric
  • Pain
  • Limp
  • Functional difficulties

REFER!
Lower Extremity Takeaways

• In-toeing and knock knees are normal!
  • Let them grow it out
• Four “F”s of DDH
• All adolescents with knee or groin/thigh pain should get AP and frog pelvis x-rays
  • SCFEs require urgent medical attention

Thank you!

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