Developmental Torsion in the Long Bones of the Leg

Assessment and Perspective on an Aspect of Child Development

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Introduction

This article describes normal and abnormal developmental changes in orientation of joints in the legs. Knowledge of these developmental pathways is essential for working with children. It provides the practitioner with valuable insight to where each child is in this developmental sequence, allowing reasonable expectations to be set for structural work, and may point to abnormal development beyond the scope of the practitioner, requiring referral. While there is a general developmental pathway, there is substantial individual variation. Understanding this developmental variability and the ability to assess the state of development helps set realistic goals for structural integration for adults.

This article describes methods to accurately assess the present state of relationships between the axes of the ankle, knee, and hip joints. For children who are far from the center of the bell curve in these dimensions, orthopedic referrals may be indicated. If a child is seen at intervals during the years of growth and development, his progress can be tracked from year to year providing a fuller picture.

During growth, the long bones of the leg change progressively between birth and maturity; the femur and tibia twist along their length, progressively changing the angular relationship between the axes of the ankle joint and knee joint. Similarly, this same relationship exists between the axis of the knee joint and a plane through the superior end of the femur. Although developmental rotations have a recognizable path, both the starting place and pace of change vary substantially from person to person, even between the two legs of the same person. The resulting orientation of the joints varies widely between people and is never identical for the two legs of any individual.

Nomenclature Ambiguities

The term 'tibial torsion' refers *both* to the developmental process of twist along the length of the tibia, and the final state of the relationship between the axes of rotation of the knee joint and ankle joint. When reading the literature on this subject, be alert to this potential source of ambiguity by understanding which aspect of tibial torsion is being discussed, and read between the lines for disambiguation. When speaking and writing on this topic, it is important to provide clarity on this distinction. Similarly, 'femoral torsion' refers to both the progressive developmental twist along the length of the femur and to the final state of this relationship.

Relationship Between the Knee and Ankle Axes of Rotation

Normal Course of Development

The knee joint and ankle joint are both hinge joints. Each of these two joints has one axis of rotation and very little other movement. In standing, the axis of rotation of each joint will normally be close to parallel to the ground. However, when viewed from above or below, the axis of rotation of the knee joint is usually not parallel to the axis of rotation of the ankle joint. Dr. Rolf's statement that these joints should operate in parallel is simply false and has frustrated and confused generations of structural integrators.

At birth, the axis of rotation of the ankle (talocrural) joint is normally internally rotated with respect to the axis of rotation of the knee joint. Ten degrees of internal rotation of the ankle joint is considered average, with a range of 5-12 degrees. As the tibia elongates during growth, it twists along its length so the axis of rotation of the ankle joint progressively shifts from internal rotation toward parallel (and usually beyond parallel). In adulthood, any amount of external rotation of the ankle joint with respect to the axis of the knee joint (between 5 degrees and 18 degrees) is considered normal. In their developmental journey the knee and ankle joints may be briefly parallel to each other at age five or six. About 80% of this rotational journey is complete by age eight, but not fully complete until physical maturity in the late teens or early twenties.

Abnormal Development

Development that differs from the norms in starting place, pace of change, and/or final orientation is considered abnormal.

Starting place: At birth there may be more or less internal rotation position of the axis of ankle joint than the normal range (5-12 degrees of internal rotation at birth is considered normal).

Pace of change: The rate of change of the relationship between the axes during growth may be slower or faster than typical. Occasionally there is a complete failure of tibial torsion where the adult has the infantile state of ankle axis internally rotated with respect to the axis of the knee joint. Rate of change may be more rapid than typical depending on the starting point and may result in greater than normal tibial torsion in adulthood.

Final orientation: Final degree of tibial torsion at maturity may be more or less than the normative values of 5-18 degrees of external rotation of the axis of the ankle joint with respect to the axis of rotation of the knee joint. This final position is the sum result of the starting position and the rate of change. While the two legs of one person never have identical tibial torsion, it is desirable that they not be greatly different from each other. Differences of greater than 7 degrees of final tibial torsion between the two legs may be biomechanically problematic.

Relationship Between the Knee Axis of Rotation and the Plane of the Superior Portion of the Femur

Normal Development

Since the hip joint is a ball-and-socket joint, the angular relationship between the joints at the two ends of the femur must be assessed in a different way than the angular relationship between the two ends of the tibia. The standard method is to consider a plane through the center of the ball of the femur – the greater trochanter and superior quarter of the shaft of the femur. Extend this plane inferiorly past the knee. Note the relationship of the axis of the knee to this plane. Rarely will the axis of rotation of the knee be parallel to this plane.

At birth, the axis of the knee joint is usually internally rotated about 40 degrees. 30-45 degrees is a normal range. Just as with the tibia, the femur rotates along its length during development, classically ending at 15 degrees of internal rotation, with 5-20 degrees considered normal range. Internal rotation of the axis of the knee with respect to the plane described through the upper part of the femur is called anteversion. The whole normal range of development is within the anteverted range. If the axis of rotation of the knee is externally rotated with respect to the plane through the superior part of the femur, this is called retroversion. Femoral retroversion is by definition abnormal. This developmental torsion is about 50% complete by age eighteen months, and 80% complete by age eight, and not fully complete until physical maturity.

Abnormal Development

Starting place: Although uncommon, it is possible for there to be greater than 45 degrees of anteversion at birth. It is similarly uncommon but possible for the degree of anteversion at birth to be less than 35 degrees.

Pace of change: The progressive external rotation of the axis of the knee joint with respect to the plane through the superior part of the femur may be normal, too fast, too slow, or nonexistent.

Position outside norms for developmental stage: At any stage of development and in maturity, femoral torsion position may be incorrect. A high normal or excessive anteversion at birth may be compensated by a faster rate of developmental torsion, or exacerbated by a slow rate of developmental torsion. Similarly, a low normal or insufficient initial anteversion will interact with developmental torsion rate for better or for worse.

Additional Factors

Position of Femur in Acetabulum

The sum of the tibial torsion and femoral torsion in each leg are major factors determining the toe-in or toe-out position of the foot. There are two additional factors contributing to this position. The femur may have an equilibrium position in the acetabulum with any degree of internal or external rotation permitted by the structure of the acetabulofemoral joint. This is a sum of tensional forces spanning between the femur and the hemipelvis. The practitioner can readily assess this factor by slowly internally and externally rotating the femur and looking for the neutral point where the least effort is required to roll in either direction.

Direction the Acetabulum Faces

Consider a plane lying on the rim of the acetabulum, and then a perpendicular line to this through the center of the acetabular cup. What direction does this line point? Normally this line has an antero-inferior orientation. The fact that the superior border of the acetabulum is lateral to the inferior border is important for weight bearing. The anterior portion of the rim of the acetabulum is normally medial to the posterior edge of the rim, but by a variable amount. Added to the tibial torsion and femoral torsion, this acetabular angle adds a variable amount of toe-in to the final stance. Like internal rotation of the knee joint axis with respect to the orientation of the superior part of the femur, this normal position of the acetabulum is referred to as anteversion. Like anteversion in the femur, acetabular anteversion varies from person to person and may not be the same in the two sides of the pelvis. In hip replacement surgery, cup placement is considered critical and 15 degrees of anteversion per side is considered ideal. This dimension is not assessable by the manual therapist but requires radiology. (For a review of the literature on this topic see Wan et al 2009.)

Metatarsus Adductus and Abductus

In the foot the five metatarsal bones may be collectively held in either adduction or abduction with respect to the row of three cuneiform bones plus the cuboid bone. This can give an impression of toe-in or toe-out, but must be assessed separately and not conflated with either the orientation of the ankle (talorcural) joint axis or the orientation of the hindfoot. Forefoot adduction or abduction can be assessed by first observing the apparent angulation (medial or lateral) of the metatarsal group at the metacarpophalangeal line, and then mobility testing this set of joints by stabilizing the cuneiform and cuboid group with one hand while slowly adducting and abducting the metatarsal group with the other hand.

Assessment

Assessment of components of internal and external rotation of the leg is done in segments that are then added together to arrive at an understanding of the big picture of torsional relationships in the legs and feet including toe-in, toe-out, and knee orientation. Each piece of data must be considered in light of the others to understand the structure of each person's body. From this assembled understanding, realistic expectations can be made for treatment, and in some cases, orthopedic referral may be necessary.

Global Visual Assessment

Have the client stand naturally. How do his feet land? If you observe the client to look down and carefully place his feet, ask him to shake it out and let his feet land naturally. Visually assess each leg and foot separately. As an initial reference, consider a frontal plane through the anterior spines of the iliac crests and a midsagittal plane perpendicular to this through the pubic symphysis. Extend both planes to the floor. For the purpose of this examination, ignore relationships superior to the pelvis. See the relationship of each foot to these planes. Compared to the midsagittal plane through the pubic symphysis, each foot may be internally rotated, straight ahead, or externally rotated. It is not normal for the two feet to be in the same position relative to the sagittal plane. Be alert to the forefoot adduction or abduction situation mentioned above. Note these results.

Standing Hip Rotation Assessment

Sit behind the client and place your right hand to stabilize the right knee. With your left hand take control of the left iliac crest and slowly rotate the pelvis on the right femur first toward internal rotation, rest back to neutral, then slowly toward external rotation. Note the range and ease of movement. Trade hands to similarly assess rotation in the left hip.

Assessment of Tibial Torsion

These instructions are for the right leg; reverse them for the left leg.

Have the client lie comfortably supine on the table. Ask the client to relax.

Visually assess apparent degree of turnout of each foot. It is typical for the feet to turn out when supine, but they may be straight ahead or turned in. The two will only rarely have the same degree of turn out or turn in. How does the degree of turn out or turn in compare with the standing position?

Sit at your client's right side facing his lower leg.

Place your left hand under the client's right knee. Slowly flex the knee about 20 degrees in the orientation from where it lies on the table (whether the knee is in neutral or rotated lateral or medial, the practitioner is lifting and flexing the knee without reorienting the knee joint). Note the path of the knee compared to a line perpendicular to the table. The knee will most often travel angled lateral to the vertical, but may travel vertical or angled in toward the midline. Return the knee to the table, leaving your hand under it.

With your left hand under the knee internally or externally rotate the femur so the knee may be able to flex upward closer to a vertical. Again bend the knee up about 20 degrees. Note how close to a vertical path it travels. Let the knee down.

As needed, make a succession of rotational adjustments to the position of the femur until the knee can be raised perpendicular to the table. Then, lower the knee to the table and use your left hand to maintain this rotational position of the femur. While maintaining this femur position place your right hand on top of the right foot with your second metacarpophalangeal joint on the talus, the palm of the hand distal to that on the top of the foot, and the fingers and thumb wrapping around the ankle to give good control of the talus. With this grip, dorsiflex the ankle and specifically move the talus on the mortice. Do not allow movement in any joint of the foot distal to the ankle (talocrural) joint. Particularly avoid movement in the talonavicular joint. As you make this dorsiflexion, note the direction of travel of the foot with respect to a line perpendicular to the table. Use the table as a plane of reference. The angular deviation of the path of the foot from the vertical is the tibial torsion of this leg. It may be either internally or externally rotated, or rarely perpendicular to the table. Note the direction and degree of this angular path.

Now assess the left leg.

Assessment of Femoral Neck Position in Acetabulum and Preparation for Assessment of Femoral Torsion

These directions are for the right leg, reverse for the left.

With the client comfortably supine, sit facing the client's right thigh. Place a relaxed right hand under the right knee initially as a monitoring hand. With your left hand locate the greater trochanter. Locate the antero-posterior center of the greater trochanter. On the center of the greater trochanter make a slow strong medial push exactly parallel to the plane of the table. As you push, observe whether the femur rotates internally, externally, or does not rotate. If the femur does not rotate, this means the neck of the femur is parallel to the plane of the table, in the frontal plane. If the femur externally rotates, this means it was sitting externally rotated. Similarly, if the femur internally rotates when you push straight medially on it, this means it was sitting internally rotated.

If the neck of the femur is found to not be parallel to the plane of the table, use the right hand under the knee to rotate the femur to an approximation of parallel to the table and maintain it in this position. With your left hand again, push medially on the center of the greater trochanter to observe whether the femur rotates or not. If the femur does not rotate you are ready for the next step. If the femur still rotates when you push medially on the greater trochanter, make further rotational adjustments with your right hand on the distal femur until you arrive at a state where a straight medial push on the greater trochanter does not rotate the femur. Note the direction and degree of correction you had to make to achieve placing the neck of the femur parallel to the table. This is a measure of how the femur sits internally or externally rotated with respect to the acetabulum. Compare this with your observation of rotational range in standing.

Shift your left hand to grasp the greater trochanter. Using both hands prevent further rotation of the femur. While maintaining the femur precisely in this rotational orientation with the neck parallel to the table, use your right hand to flex the knee about 20 degrees. Observe the path of the knee compared to a line perpendicular to the table. The knee will usually travel angled toward midline demonstrating the amount of femoral anteversion. Less commonly, the knee will rise straight up or deviate laterally showing the degree of femoral retroversion. Note this direction and degree.

Now assess the left leg.

Summary of Assessment

You now have several pieces of data for each leg:

- Position of femur angled from acetabulum as anteverted, retroverted, or straight lateral
- Femoral Torsion
- Tibial Torsion
- Forefoot adduction or abduction

With this collection of data you are now in a position to understand how foot position, whether pointing in or out, relates to knee tracking, and how both of these relate to how the femur is sitting in the acetabulum with respect to internal or external rotation. At birth, given the ideal numbers of 15 degrees of acetabular inversion, 40 degrees of femoral anteversion, and 10 degrees of internal tibial torsion, this sums to 65 degrees of internal rotation per leg. It is clear how babies are toe-in at birth. By age eight when 80% of the developmental rotation should have occurred, this should be reduced by 38 degrees per leg to 27 degrees per leg. In adulthood, if we take an average of 12 degrees of tibial external torsion and 15 degrees of femoral anteversion, that sums to 3 degrees of toe-in per average leg. If 8 degrees of toe-out is desirable in stance, that means the femoral neck sits 11 degrees externally rotated in the acetabulum.

There may be wide variation in all factors and compromises must be considered to achieve the greatest ease and comfort for each individual. For example, if the sum of torsions in the legs would give a strongly toe-in position, then insisting on standing and walking with the feet parallel could leave the hip joint persistently operating at the end of the range of motion, which would be hard on the joints and require substantial muscular effort to maintain.

Standing a little toe-out is considered normal by giving a wider base of support and providing more stability for the structure. From a slightly turned-out stance it is also more efficient to start walking in a turn. When the feet are parallel, the foot on the side the person wants to walk toward must be picked up before the person can start walking to that side, left or right. On the other hand, with the feet a little turned out in standing, it is possible to initiate walking to one side more quickly and with more stability. This element of agility provides both comfort and safety.

Conclusion

Each person is unique, like a snowflake. Accurately assessing the unique positional relationships of the joints in each person's legs and understanding the developmental basis of these unique relationships creates realistic goals for soft-tissue manipulation and movement awareness education to provide ease and grace for that child or adult.

Jeffrey Burch was born in Eugene, Oregon in 1949, and grew up there except for part of his teen years in Munich, Germany. He was educated at the University of Oregon, Portland State University, and the University of Pavia, Italy, earning bachelor's degrees in biology and psychology and a master's degree in counseling. Jeffrey received his Rolfing® Structural Integration certification in 1977 and his advanced Rolfing certification in 1990. He trained extensively in cranial manipulation with French osteopath Alain Gehin, and in craniosacral therapy with the Upledger Institute. Jeffrey trained to the instructor level in visceral manipulation under Jean-Pierre Barral and his associates. He has made substantial innovations in visceral manipulation, particularly for the thorax. Jeffrey has also developed groundbreaking new joint-mobilization techniques. He practices in both Eugene and Portland, Oregon and offers continuing education courses at several locations including Eugene, Oregon; Longmont, Colorado; Chicago, Illinois; and Newton Massachusetts. For more details see www.jeffreyburch.com/biography.

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