REVIEW

Observational gait analysis

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Purpose of review
The review is aimed at practising paediatricians who want to improve their clinical skills in observational gait analysis. Many paediatric complaints relate to problems of walking or limb alignment, and only a small proportion of these are pathological. With a deeper understanding of normal gait and a framework to conduct an observational analysis, the clinician can feel more confident diagnosing and recognizing those walking patterns that need further investigation.

Recent findings
Advances in instrumented gait analysis over the last two decades have provided deeper insights into the mechanisms of walking, how to interpret gait deviations, and their effect on locomotion. This has helped improve the quality of observational gait analysis and, in many ways, defined its limitations.

Summary
This review explains the components of normal gait and provides a structured approach to observational gait analysis. It also discusses the cause of limps and expands upon the importance of understanding rotational deformities. Finally, some tools to enhance the observational analysis are presented.

Keywords
gait, observation, skills

INTRODUCTION

In our technology-focused practices, it is easy to forget that taking a medical history and examining a child is where all management begins. In the orthopaedic examination, observing a child's gait can often provide a diagnosis before any hands-on examination or investigation is performed. Recognizing normal gait, its variations and deviations is a valuable skill requiring core knowledge and practice.

Gait analysis is a broad term applied to any method that attempts to understand human locomotion. Observational gait analysis is a 'no tech' tool that only requires time and space, 2D video a 'low tech' option that can provide deeper insights into what is being observed and instrumented 3D instrumented gait analysis a 'high tech' option requiring specialised laboratories dedicated to the study of walking [1▪].

The revelations from instrumented gait analysis have trickled down into clinical practice, providing the clinician with a deeper understanding of both normal and abnormal gait patterns along with a framework in which to work.

NORMAL GAIT

Gait is a complex process involving bones, joints and muscles coordinated into action by a neurological system powered by a vascular tree. The number of diseases that can affect gait is extensive, affecting one or more components.

Temporal-spatial parameters

These parameters describe the timing and spatial characteristics of gait [2]:

(1) Velocity: The speed of walking, typically measured in meters per second.
(2) Cadence: The number of steps taken per minute.
(3) Step length: The distance between consecutive points of initial contact of the opposite feet.
(4) Stride length: The distance between consecutive points of initial contact of the same foot.

Gait cycle

The gait cycle [1▪] is divided into two main phases, stance and swing, and is measured from the initial

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KEY POINTS

- Performing an observational gait analysis requires baseline knowledge of the gait cycle.
- A structured approach to observational gait analysis is essential.
- Practice is required to become competent.

contact of the foot to the following initial contact of the same foot [3] (Fig. 1). Two periods in which both feet are on the ground, known as 'double support', occur during the stance phase.

Stance phase: This phase accounts for approximately 60% of the gait cycle and includes:

(1) Initial contact: The moment the foot touches the ground.
(2) Loading response: The period from initial contact until the opposite foot leaves the ground.
(3) Midstance: The body progresses over a single, stable limb.
(4) Terminal stance: The heel of the stance foot rises, and the body moves ahead of the stance limb.
(5) Pre-swing: The period just before the stance foot leaves the ground, ending the stance phase.

Swing phase: This phase makes up the remaining 40% of the gait cycle and includes

(1) Initial swing: The foot leaves the ground, and the limb accelerates forward.
(2) Midswing: The limb swings forward until the tibia is vertical.
(3) Terminal swing: The limb decelerates in preparation for initial contact.

Kinematics

Kinematics involves studying joint motion without considering the forces that cause them. The gait laboratory contributes to our understanding of kinematics, and when this knowledge is applied to observational analysis, identifying gait patterns and pathologies is greatly enhanced. Studying the kinematics in the sagittal plane to identify gait deviations is beneficial.

Hip

(1) At initial contact of the heel, the hip is usually flexed to around 40° (Fig. 2).
(2) During the stance phase, the hip extends smoothly to around 0°.
(3) In preswing, the hip starts to flex to propel the limb forward.

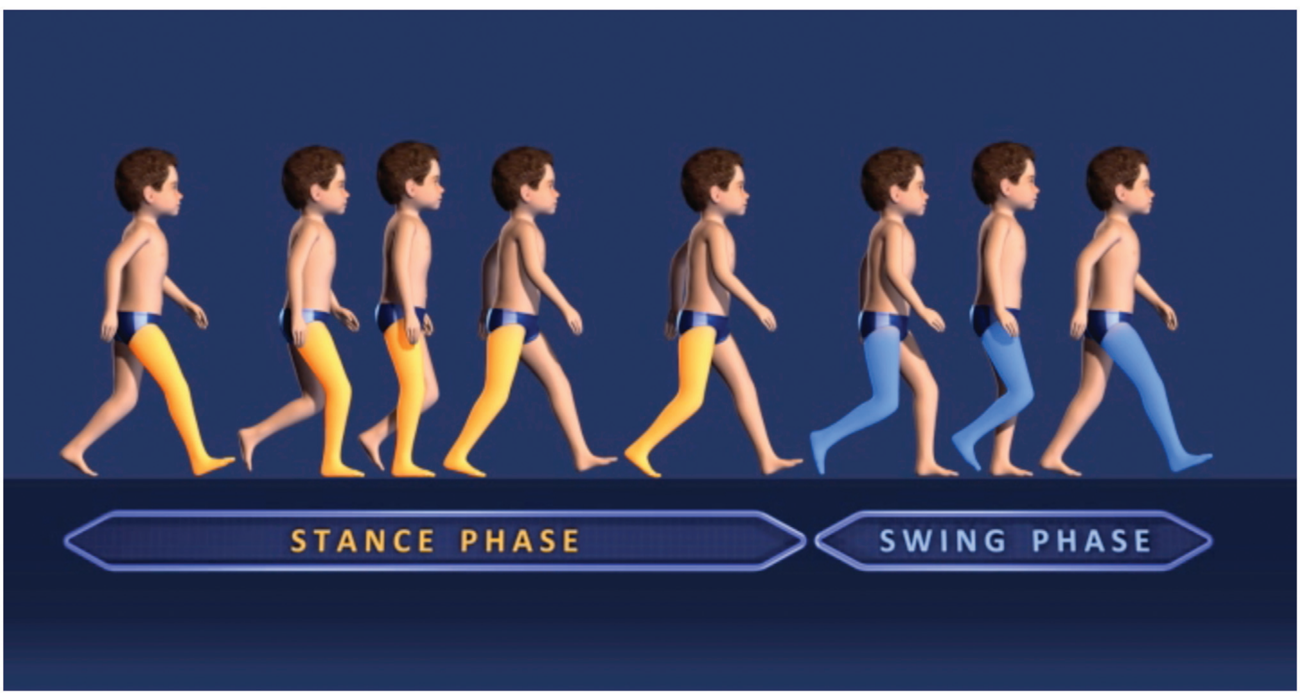

FIGURE 1. The normal Gait cycle.

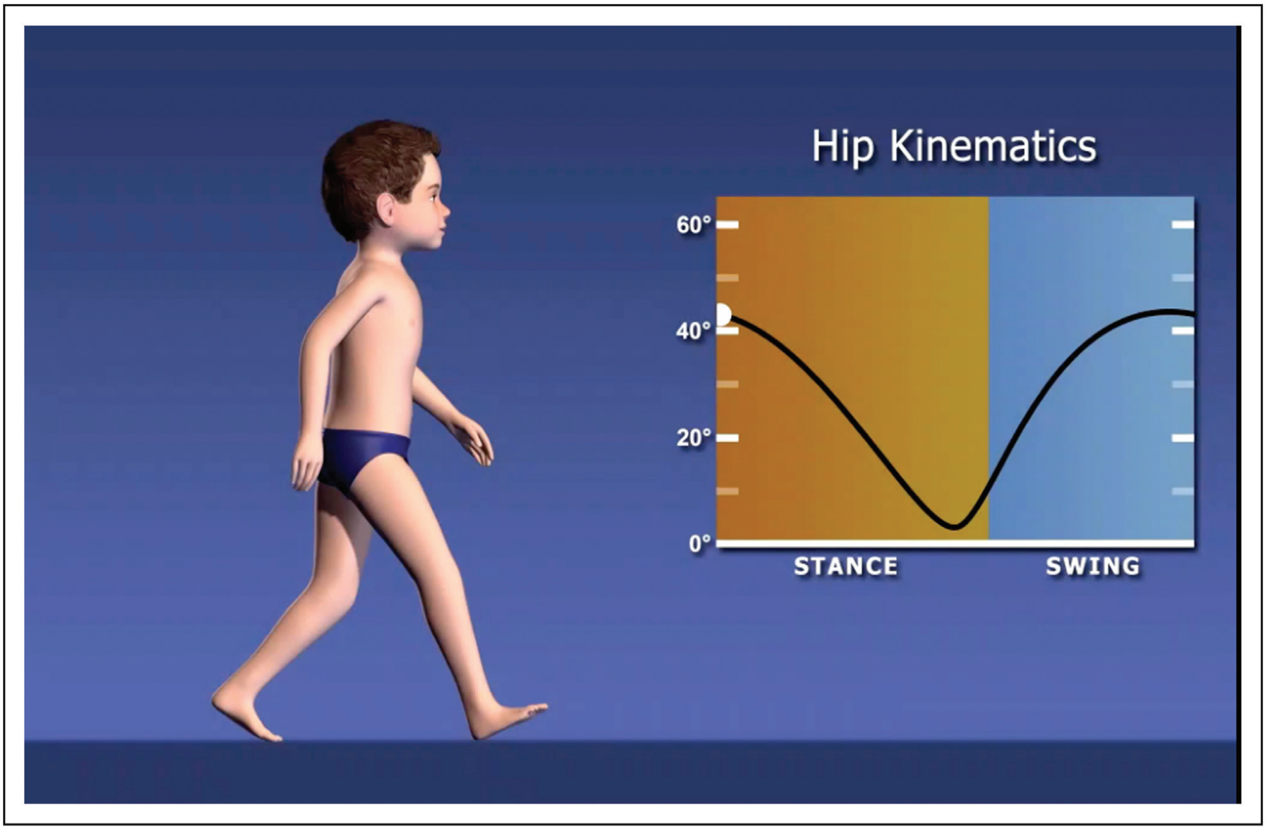

FIGURE 2. Hip kinematics.

(4) The flexion rate reduces at the end of swing, preparing the limb for initial contact.

Knee

(1) At initial contact, the knee slightly flexes in shock absorption (Fig. 3).
(2) It then extends to a maximum of around 10° during stance as the body moves forward.
(3) The knee rapidly flexes at preswing, continuing into mid-swing, clearing the foot.
(4) Later in the swing phase, the knee extends, bringing the limb forward and positioning the foot for initial contact again.

Ankle

(1) Initial contact is made with the heel as the knee shock absorbs (Fig. 4).
(2) The foot plantar flexes and complete contact is made.
(3) The ankle dorsiflexes as the leg moves forward, and at the end of stance, it plantar flexes for push-off.
(4) During swing, the ankle dorsiflexes to obtain clearance from the ground.

Kinetics

Kinetics examines the forces that cause movement:

(1) Ground reaction forces: Forces exerted by the ground on the body during walking.
(2) Joint moments: The rotational forces acting on joints.
(3) Muscle activity: The timing and intensity of muscle contractions during gait.

The measurements are derived from 3D gait analysis using data captured from force plates embedded in the gait laboratory floor that can then be paired with the gait cycle data from motion capture. Whilst this is not part of observational gait analysis, an understanding can be helpful.

PREREQUISITES FOR NORMAL GAIT

Jacquelin Perry [4▪▪] identified the five requirements for normal gait as

(1) Stability of the weight-bearing foot
  (a) Throughout the stance phase: The foot must provide a stable base of support during the

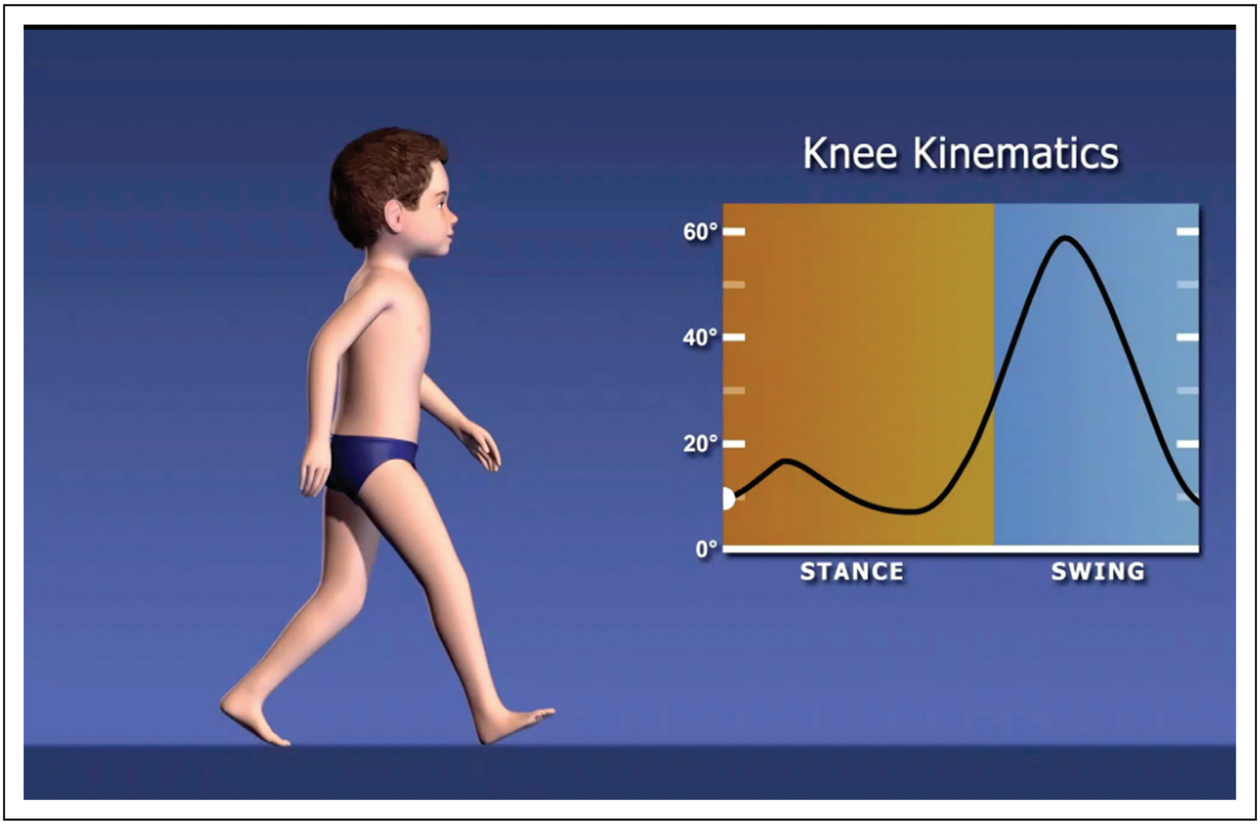

FIGURE 3. Knee kinematics.

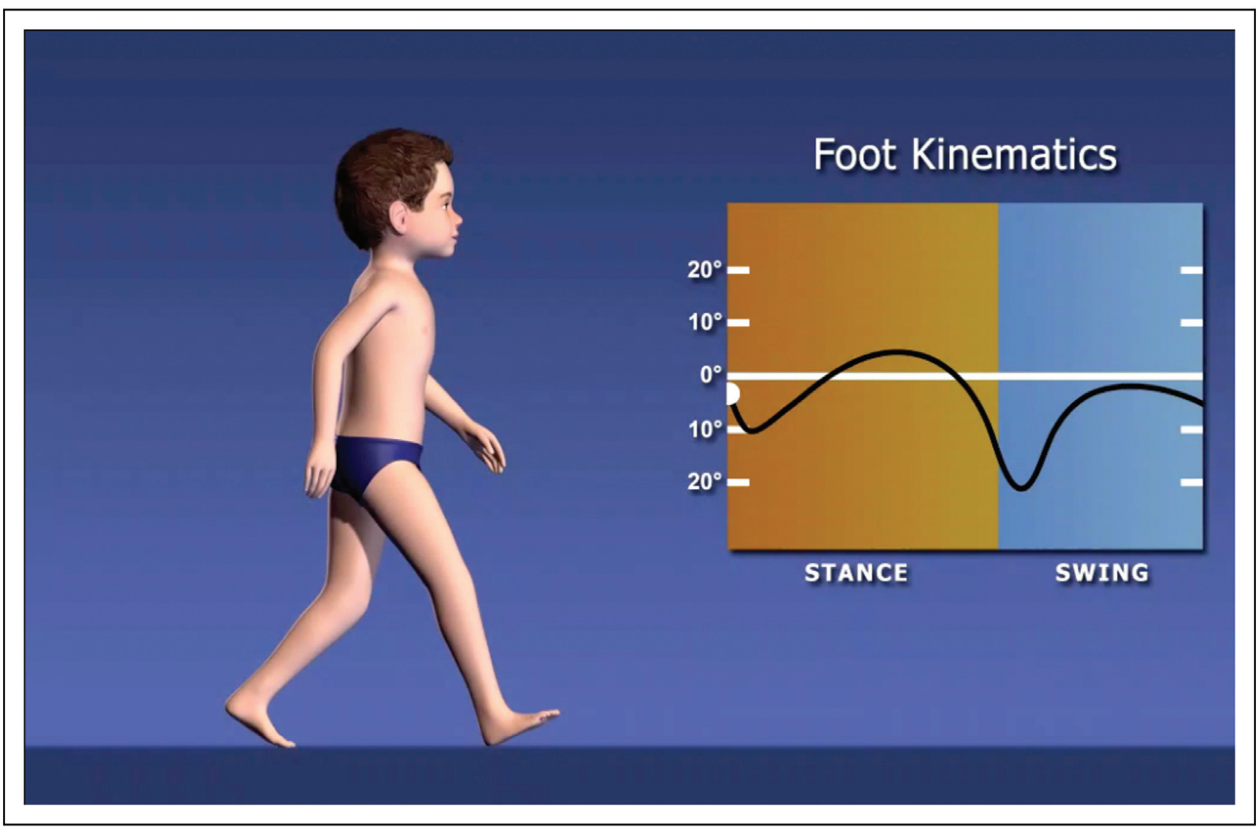

FIGURE 4. Ankle and foot kinematics.

stance phase to support body weight and maintain balance. This stability is crucial for efficient energy transfer and forward propulsion.

(2) Clearance of the non-weight-bearing foot
  (b) During the swing phase: The nonweight-bearing foot must clear the ground during the swing phase to prevent tripping and ensure a smooth transition to the next step. This requires adequate hip and knee flexion and ankle dorsiflexion.

(3) Pre-positioning of the foot
  (c) During terminal swing: The foot must be correctly positioned in preparation for the following initial contact. Proper prepositioning ensures that the foot strikes the ground in a manner that facilitates shock absorption and stability.

(4) Adequate step length
  (d) For efficient movement: Adequate step length is necessary to cover ground efficiently and maintain a steady walking rhythm. This requires proper coordination and strength of the lower limb muscles.

(5) Energy conservation
  (e) Efficient use of energy: Normal gait should minimize energy expenditure. Efficient gait patterns reduce the metabolic cost of walking, making it easier to sustain over long distances. This is achieved through smooth and coordinated movements that optimize the use of muscle forces and joint mechanics.

AN APPROACH TO OBSERVATIONAL GAIT ANALYSIS

Conducting a competent observational Gait analysis requires exposure and space. The patient's body contours must be seen (ideally, form-fitting clothing), and the feet must be bare. There must be enough room to watch at least four strides from the side, front and back without impediment, with good lighting and minimal background distraction. Most examination rooms are inadequate for this, so judicious use of corridors may be required.

Observe the overall alignment and body segment proportions while the patient quietly stands. From the front, genu varum or valgum can be appreciated, and from the side, flexion of the hip and knee may be present, as can knee hyperextension. The spine should always be examined, and a forward bend test for scoliosis should be performed. Pelvic obliquity should be noted and whether this corrects with blocks under the foot potentially indicating a leg length difference if no joint contractures are present.

The gait examination starts at the head. Are there any dysmorphic features? Is the patient showing any signs of pain or discomfort? As the head is essentially at the end of a body pendulum, any lower limb imbalance can be detected by excessive excursion from side to side or back to front. Excessive vertical excursion could indicate an uncompensated limb length discrepancy or hip instability. Any excessive motion is energy inefficient, and these patients will likely fatigue over time.

It is then helpful to look at the foot and ankle. What is the shape of the foot? What part of the foot comes in contact with the ground first? In normal gait, the heel strikes first, and then the foot rolls onto the lateral border across the forefoot to leave the ground with pressure under the first metatarsal head. A series of smooth and coordinated movements occur at the ankle and foot, known as rockers.

(1) First rocker is the heel making contact with the ground, and the foot plantar flexes to bring the sole in contact with the ground.
(2) Second rocker is a process of ankle dorsiflexion that occurs as the limb moves forward over the fixed foot and pressure moves across the sole.
(3) Third rocker is rapid plantar flexion (push-off) that helps propel the limb forward in preparation for swing.

It is also helpful to consider a fourth motion, dorsiflexion, during a swing, which clears the foot from the ground.

Finally, it is essential to observe the angle the foot takes in the direction of walking, the foot progression angle, which is the final expression of the limb's rotational profile.

There is much to be learned from observing the foot. The posture the foot makes on loading could reveal an underlying disease, such as the high-arched clawed toe of hereditary motor sensory neuropathy or an antalgic flat foot of a tarsal coalition. Initial contact with the forefoot could indicate a calf contracture or spasticity, and uncontrolled positioning of the foot occurs with nerve injuries and spinal dysraphism. An intoe gait could be normal variation or due to spastic diplegia. What is essential is the identification of variation and contextualization of this with the complete gait analysis and the rest of the examination.

At the knee, the examiner looks for stability in stance and the patellar progression angle (the patellar alignment to the line of walking) as a sign of femoral rotation. Knee thrusting into varus or valgus indicates joint instability that may be intraarticular (varus as in Blount disease) or extraarticular due to collateral ligament failure. The knee should slightly flex on initial contact and then extend, but this can be lost due to stiffness or pain, and a bent knee will induce an apparent leg length discrepancy. If the knee remains extended during swing, clearance is difficult, and the leg may have to be circumducted for clearance or vaulting over the leg.

The hip being deep is often difficult to observe. A fixed flexion contracture reduces the range of limb progression and is often compensated for by posterior pelvic tilt and compensatory lumbar lordosis. Once a hip reaches a threshold of stiffness, the patient will rely on increased pelvic rotation, bypassing the hip joint and using the lumbar spine to move the limb forward.

A more common scenario involving the hip that causes gait abnormalities is the failure of the abduction mechanism, which produces a Trendelenburg gait. The abductor mechanism can be likened to a teeter-totter, where the pelvis is on one side, and the other is the greater trochanter and femoral neck, with the hip joint being the hinge point. If any of these components is compromised, the pelvis will not remain level during stance and drop on the opposite side. To maintain balance, body weight must be moved over the affected hip, which is the truncal sway seen in walking. Causes of a Trendelenburg gait are numerous, but the most common are as follows:

(1) Dislocated hip
(2) Slipped epiphysis
(3) Painful joint
(4) Abductor weakness
(5) Coxa vara
(6) Coxa breva
(7) Trochanteric overgrowth

Often, combinations of the above produce gait disturbance, such as Perthes, which can be painful, distort the joint and cause shortening of the femoral neck or a hip dislocation in which the fulcrum is displaced, and the abductor muscles are ineffective.

CAUSES OF ABNORMAL GAITS

The normal gait pattern is symmetrical and smooth in its execution. If this natural rhythm is disturbed, we perceive this as a limp.

Limps can be caused by

(1) Pain
(2) Weakness
(3) Discrepancy
(4) Instability
(5) Stiffness
(6) Malalignment
(7) In-coordination

And produce the following patterns or combinations thereof

(1) Antalgic
(2) Short limb
(3) Trendelenburg
(4) Stiff legged
(5) Spastic
(6) Ataxic

However, it should be recognized that on occasion, significant musculoskeletal disease can be present, and no gait abnormality is perceived, such as with a well compensated congenital leg length discrepancy.

ROTATIONAL ABNORMALITIES

In recent years, it has become more widely recognized that rotational abnormalities play an important role in gait disturbance. Without instrumented gait analysis, these gait anomalies can be challenging to discern. Rotational deformities may arise in the femur, tibia or foot and can be mixed in site, symmetry and degree.

Internal rotation of the femur due to excessive femoral anteversion can produce hip pain, patellar maltracking, anterior knee pain, tripping and rolling of the ankle. It may not be immediately apparent in patients with compensatory external tibial torsion with a relatively normal foot progression angle. External tibial torsion can produce a pes planus with rolling over the foot. Deformity in the foot, particularly if asymmetric, will create a gait disturbance; a stiff, internally rotated club foot can produce a poor gait pattern.

To appreciate these causes of gait disturbance and identify the source of the problem, the clinician needs to understand the concept of the rotational profile. Engel and Staheli [5] defined this as

(1) Prone hip rotation: Assesses the degree of internal and external range of motion of the hi). These measurements reflect femoral torsion.
(2) Thigh-foot angle: The angle between the thigh and the foot's axis (line from heel to second toe) when the knee is flexed at 90°. Used to assess tibial torsion
(3) The transmalleolar axis measures the angle between the line connecting the medial and

lateral malleoli and the transverse plane. It provides information about the tibia's rotational alignment.

(4) Foot progression angle: This is the angle between the direction of walking and the direction in which the foot points. It is used to assess the overall rotational alignment of the lower limb during gait.

The patellar progression angle can be added to this assessment for completeness.

ENHANCING OBSERVATIONAL GAIT ANALYSIS

There are several ways to enhance observational gait analysis in the clinical environment. Appropriate clothing and environment go a long way to improving observation, but for clarity, bony landmarks can be marked with a washable marker so that tracking during walking is easier. The medial and lateral malleoli and the patellar centre can improve the rotation perception.

Two-dimensional video [6] is easy to capture on a phone. The phone should be at least 5 m from the patient and held at the patient's hip height. Portrait mode is used when walking to and from the examiner, and landscape mode is used when filming from the side. Slow motion is beneficial for filming the foot, and to avoid parallax, the examiner can track alongside the patient, matching their speed whilst filming. The captured video can be examined at another time and held permanently in the medical record.

A number of phone applications [7] allow direct measurement of joint range of motion from captured video. This may be useful in certain circumstances when instrumented gait analysis is not available, and the effect of therapies such as OnabotulinumtoxinA needs to be monitored.

Several gait scoring systems [8] have been developed to improve gait analysis and consistency in reporting. Most of these systems focus on neurological conditions such as cerebral palsy, but some are aimed at injury recovery. In general, they rely on video analysis and have not undergone rigorous testing and validation.

CONCLUSION

Observational gait analysis is an integral part of examining children who present with a 'limp.' Careful observation of the walking pattern often yields a solid differential diagnosis, making formal musculoskeletal examination and subsequent investigations more focused.

A good understanding of the components of normal gait makes observation of walking patterns easier and enhances the utility of the clinical examination. As with any skill acquisition, practice is required to be competent in interpreting gait anomalies.

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Conflicts of interest

None.

All images are the property of Assoc Prof Leo Donnan.

REFERENCES AND RECOMMENDED READING

Papers of particular interest, published within the annual period of review, have been highlighted as:
■ of special interest
■■ of outstanding interest

1. Hecht GG, Rysselberghe NLV, Young JL, Gardner MJ. Gait analysis in ■ orthopaedic surgery: history, limitations, and future directions. J Am Acad Orthop Surg 2022; 30:e1366–e1373.

The study reviews the history, limitations and future directions of gait analysis. The authors discuss traditional methods, emerging technologies and their clinical relevance, predicting increased adoption for evaluating patient outcomes and optimizing treatment strategies.

2. Wallmann HW. Introduction to observational gait analysis. Home Heal Care Manag Pr 2009; 22:66–68.
3. Chambers HG, Sutherland DH. A practical guide to gait analysis. J Am Acad Orthop Surg 2002; 10:222–231.
4. Perry J, Burnfield JM. Gait analysis, normal and pathological function. CC ■■ Press, Taylor and Francis Group; 2024.

This text is a seminal work in observational and instrumented gait analysis focusing on neuromuscular pathology. Dr Perry and Burnfield are responsible for the language of gait, pioneered analysis techniques and provided a pathway to translate these findings into clinical application.

5. Engel GM, Staheli LT. The natural history of torsion and other factors influencing gait in childhood. Clin Orthop Relat Res 1974; 99:12–17.
6. Michelini A, Eshraghi A, Andrysek J. Two-dimensional video gait analysis: a systematic review of reliability, validity, and best practice considerations. Prosthet Orthot Int 2020; 44:245–262.
7. Kulkarni VA, Kephart DT, Olleac R, Davids JR. Enhancing observational gait analysis - techniques and tips for analyzing gait without a gait lab. J Pediatr Orthop Soc North Am 2020; 2:135.
8. Rathinam C, Bateman A, Peirson J, Skinner J. Observational gait assessment tools in paediatrics - a systematic review. Gait Posture 2014; 40:279–285.