Basic Athletic Training
Course Pack A

For use in PES 385, Basic Athletic Training, SUNY Brockport.

CHAPTER

8

Assessment of Body Alignment Posture and Gait

STUDENT OUTCOMES

1. Describe somatotyping and identify the three basic somatotypes.
2. List the key components of a static postural assessment.
3. Identify normal and abnormal postural findings.
4. Describe cross syndrome in relation to faulty posture.
5. Explain the kinematics of the hip, knee, lower leg, ankle, and foot and identify the muscles that are responsible for coordinated and smooth gait.
6. Define the gait cycle and its phases.
7. Differentiate normal parameters of gait including base width, step length, stride length, lateral pelvic shift,

vertical pelvic shift, and pelvic rotation.

8. Identify differential diagnosis of antalgic gait.

INTRODUCTION

The evaluation of a patient’s body alignment, posture, and gait, along with a solid health history, can provide the practitioner with valuable insight into the patient’s pathology or potential pitfalls. This is especially true when assessing chronic injuries or during the preparticipation examination. This chapter begins with describing somatotyping and an examination of different body types followed by an overview of posture. Key terminology needed to understand the importance of optimal posture in maintaining normal function is presented. Information on how to conduct a postural assessment, identify normal and faulty posture, and interpret findings is included. The second half of this chapter focuses on the principles of gait and gait assessment.

SOMATOTYPING

Prior to beginning an assessment of posture or gait, it is important to note the overall body appearance. Although body typing provides a general appearance, it can be helpful to identify normative values for each individual patient. Somatotyping taxonomy was developed in the 1940s, by American psychologist William Herbert Sheldon, to categorize the human body according to the relative contribution of three fundamental elements. Somatotypes are named after the three germ layers of embryonic development: the endoderm (develops into the digestive tract), the mesoderm (becomes muscle, heart, and blood vessels), and the ectoderm (forms the skin and nervous system) (**Fig. 8.1**).[1]

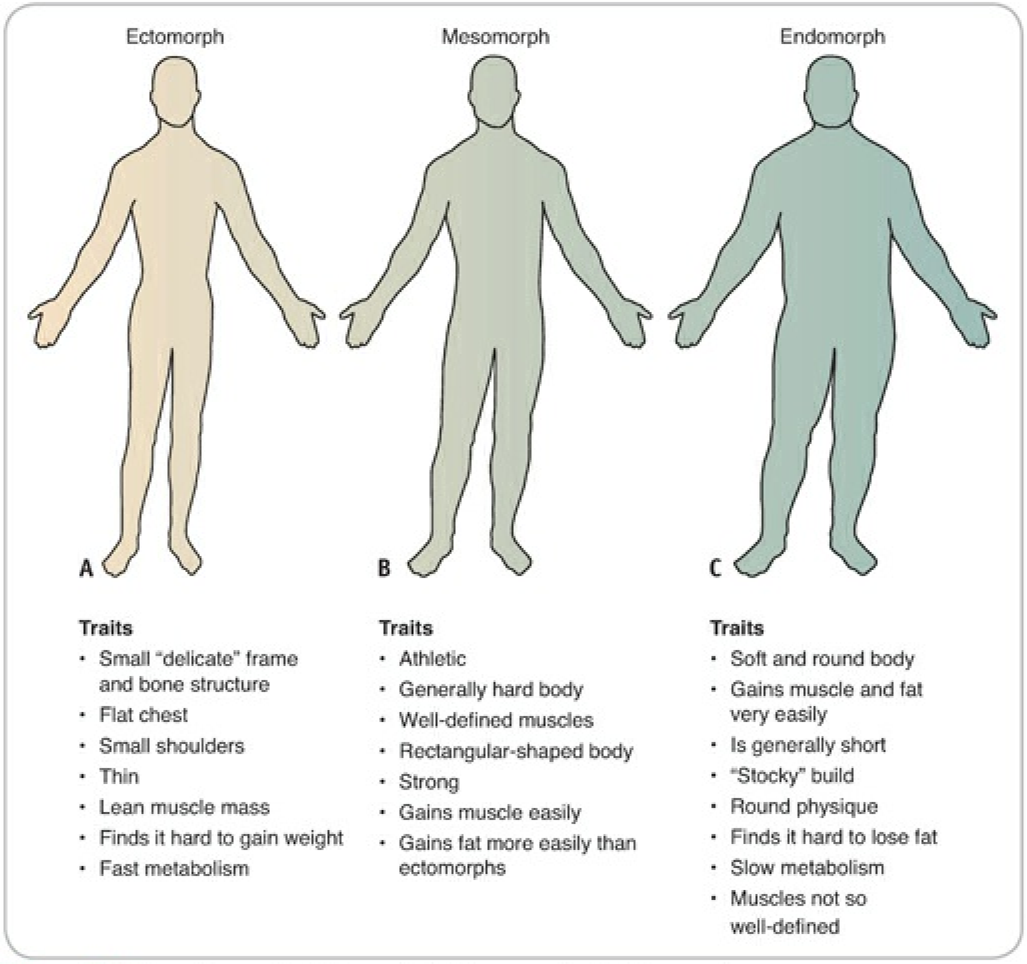

Figure 8.1. Somatotypes. A, Ectomorph. **B,** Mesomorph. **C,** Endomorph.

Ectomorph

An ectomorph is a typical lean individual. Ectomorphs have a light build with small joints and lean muscle. Usually, ectomorphs have long thin limbs with stringy muscles. Shoulders tend to be thin with little width.

Mesomorph

A mesomorph has a large bone structure, large muscles, and a naturally athletic physique. Mesomorphs find it quite easy to gain and lose weight. They are naturally strong and build muscle mass quickly.

Endomorph

The endomorph body type is solid and generally soft. Endomorphs have a tendency to gain weight very easily. Endomorphs are usually of a shorter build with thick arms and legs. Muscles are strong, especially the upper legs.

Mixed Body Type

Very often, people cannot be easily classed as one of the three main body types. Although there are some people who are purely ectomorphs, endomorphs, or mesomorphs with little or no characteristics of the other body types, very frequently, people fall into mixed categories, such as ecto-mesomorphs or endo-mesomorphs, where largely, they are like the mesomorph but with traits of the ectomorph (such as small joints or a trim waist) or traits of the endomorph (such as a tendency to gain fat easily).

ASSESSMENT OF POSTURE

> ? A 21-year-old male lacrosse player presents with long-term pain in the thoracic region. He cannot identify when his pain began or describe a specific cause or mechanism of injury. No indications of acute injury are found during inspection and palpation. How might the patient's posture factor into his current symptoms?

Regardless of the injury, evaluating the patient from head to toe is an important aspect of the assessment process. Posture control serves three main purposes:

1. Antigravity function: maintaining an erect posture and keeping eyes level
2. Maintenance of equilibrium and balance
3. Providing mechanical support for motion

Optimal Posture

Optimal posture implies balanced dissemination of body mass around the center of gravity where the compression forces on spinal disks is balanced by ligamentous tension and with minimal energy expenditure from postural muscles.[2] Joint range of motion (ROM) and muscle length and strength also play a major role in achieving optimal posture.[3]

When the body is in an upright position, the line of gravity passes anterior to the spinal column (**Fig. 8.2**). To maintain body position, this moment must be counteracted by tension in the back muscles. Other forces impacting optimal posture include body weight, tension in the spinal ligaments and paraspinal muscles, intra-abdominal pressure, and any applied external loads. When the body is upright, the major form of loading on the spine is axial, and the lumbar spine supports the weight of the body segments above it. When the paraspinal muscles are fatigued, there are increased levels of co-contraction, which also help to stiffen the spine and increase spinal stability.[4]

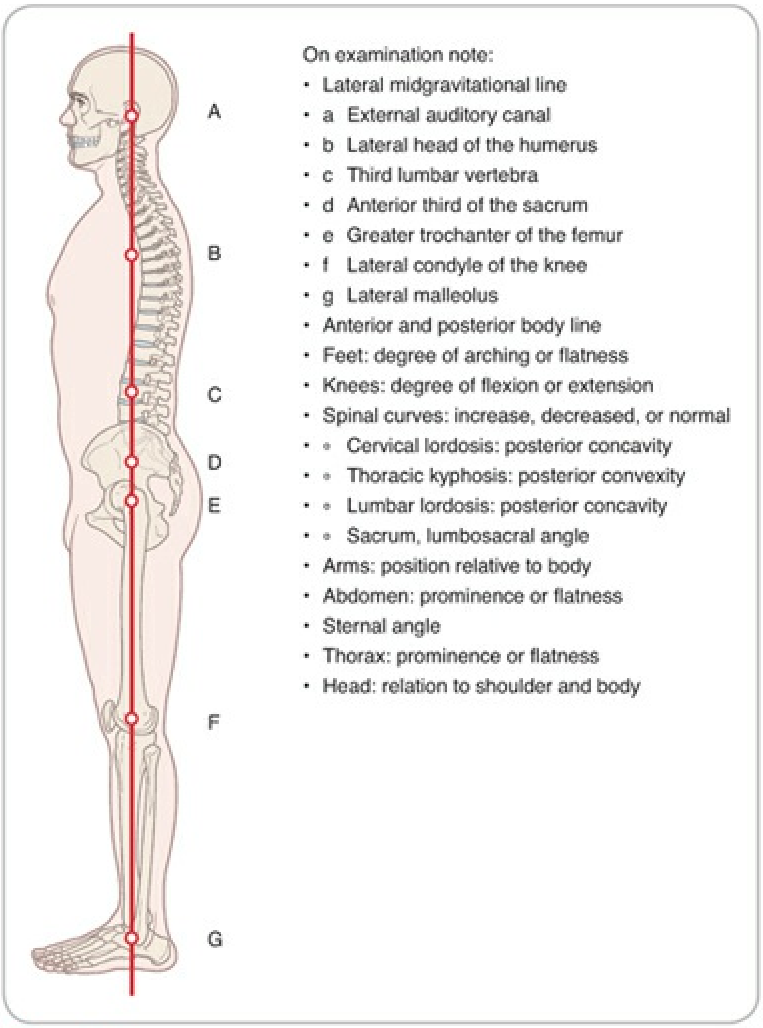

Figure 8.2. Lateral view of normal posture with midgravitational line. The line of gravity for the head and trunk passes anterior to the spinal column during upright standing. The moment arm for head/trunk weight at any given vertebral joint is the perpendicular distance between the line of gravity and the spinal column.

Optimal posture depends on maintaining normal body structure and function. As such, posture is a result of habit: Good habits result in good posture, whereas poor habits result in poor or faulty posture. Maintaining optimal posture is important in achieving pain-free, efficient body movement and motion. Failure to maintain an optimal posture often results in discomfort, pain, and dysfunction. Because posture is impacted by both the structure and function of the musculoskeletal system, examination of posture is conducted using three different assessments: (1) examination of alignment in standing, (2) tests for flexibility and muscle length, and (3) tests for muscle strength.[3]

Examination in Standing: Alignment

A quick head-to-foot visual scan by the practitioner can detect significant asymmetries in posture that will assist in identifying the cause of the patient's symptoms. For example, the patient who presents with forward head position where the ear lobes are anterior to the shoulders often also complains of neck pain. Shoulder asymmetries in height are frequently observed in unilateral overhead throwing athletes, whereas anterior shoulder position is common in patients with chronic impingement syndrome. Application Strategy 8.1 provides details of the key features used to conduct a postural assessment from the anterior, lateral, and posterior views.

APPLICATION STRATEGY 8.1

Postural Assessment Checklist

Anterior View

- Are the head and neck in the midline of the body? Is the nose centered? Does the jaw appear normal?
- Is the slope of the shoulder muscles bilaterally equal? (The level of the shoulder on the dominant side usually is lower than the nondominant side.)
- Do both shoulders have a well-rounded deltoid musculature with no prominent bony structures?
- Are any scars or muscular atrophy present in the arms?
- Is the space between the arms and body the same on both sides?
- Are both hands held in the same position?
- Does the rib cage look symmetrical with no bony protrusions?
- Are the folds of the waist at the same height?
- Are the kneecaps level and facing forward? Are the knees straight and the heads of the fibula level?

- Are the distal bony prominences of the lower leg bilaterally level?
- Are arches present on both feet? When standing in a comfortable position, do the feet angle equally?

Lateral View

- Can an imaginary, straight plumb line be drawn from the ear through the middle of the shoulder, hip, knee, and ankle?
- Does the back have any excessive curves?
- Are the elbows held near full extension?
- Do the chest, back, and abdominal muscles have good tone with no obvious chest deformities?
- Does the pelvis appear to be level?
- Are the knees straight, flexed, or hyperextended? (Normal is a position of slight flexion.)

Posterior View

- Are the head and neck centered? Is there any abnormal prominence of bony structures or muscle atrophy?
- Are the scapula at the same height and resting at the same angle? Are both scapulas lying flat against the rib cage?
- Does the spine appear to be straight?
- Is there any atrophy in the muscle groups of the shoulder and arm?
- Is the posterior side of the elbow at the same height bilaterally? Is the space between the body and elbow the same on both sides?
- Do the ribs protrude?
- Are the waist folds level? Are the posterior gluteal folds level?
- Are the skin creases on the posterior knee level?
- Do both Achilles tendons descend straight to the floor? Are the heels

straight, angled in (varus), or angled out (valgus)?

When assessing postural alignment, you should view from the anterior, posterior, and lateral views. From the **anterior view**, a straight line, perpendicular to the floor, should intersect the forehead, nose, manubrium, and umbilicus pubis and have an even spacing between the feet. Parallel lines to the floor should be used to assess the shoulders and hips. If the shoulders are equal and parallel to the floor, this would indicate symmetry between the right and left shoulders. In addition, the patient should be viewed at the anterior superior iliac spine (ASIS) level to assess if the pelvis is equal indicating symmetrical pelvic height (**Fig. 8.3**). The **posterior view** provides the practitioner with similar information as the anterior view with slightly different kinematic checkpoints. The perpendicular line should proceed from the occiput, straight down the spine to the sacrum. Feet should be equal distance from center and should be parallel. In addition, when examining the patient from a posterior view, the presence of any dark areas of skin pigmentation, such as café au lait spots, should be noted because this could indicate a possible collagen disease or abnormal growth of neural tissues (neurofibromatosis). The lower lumbar spine and sacrum should be observed for tufts of hair (Faun’s beard), indicating possible spina bifida occulta. From the **lateral view**, the joints should look stacked. The ears should be directly over the shoulders. The anterior aspect of the shoulders should be in alignment with the greater trochanter. The head, ear, shoulder, and hip should all be in a straight line to the midtarsal area on the foot. The head, pelvis, and spine are in a neutral position (**Fig. 8.4**).

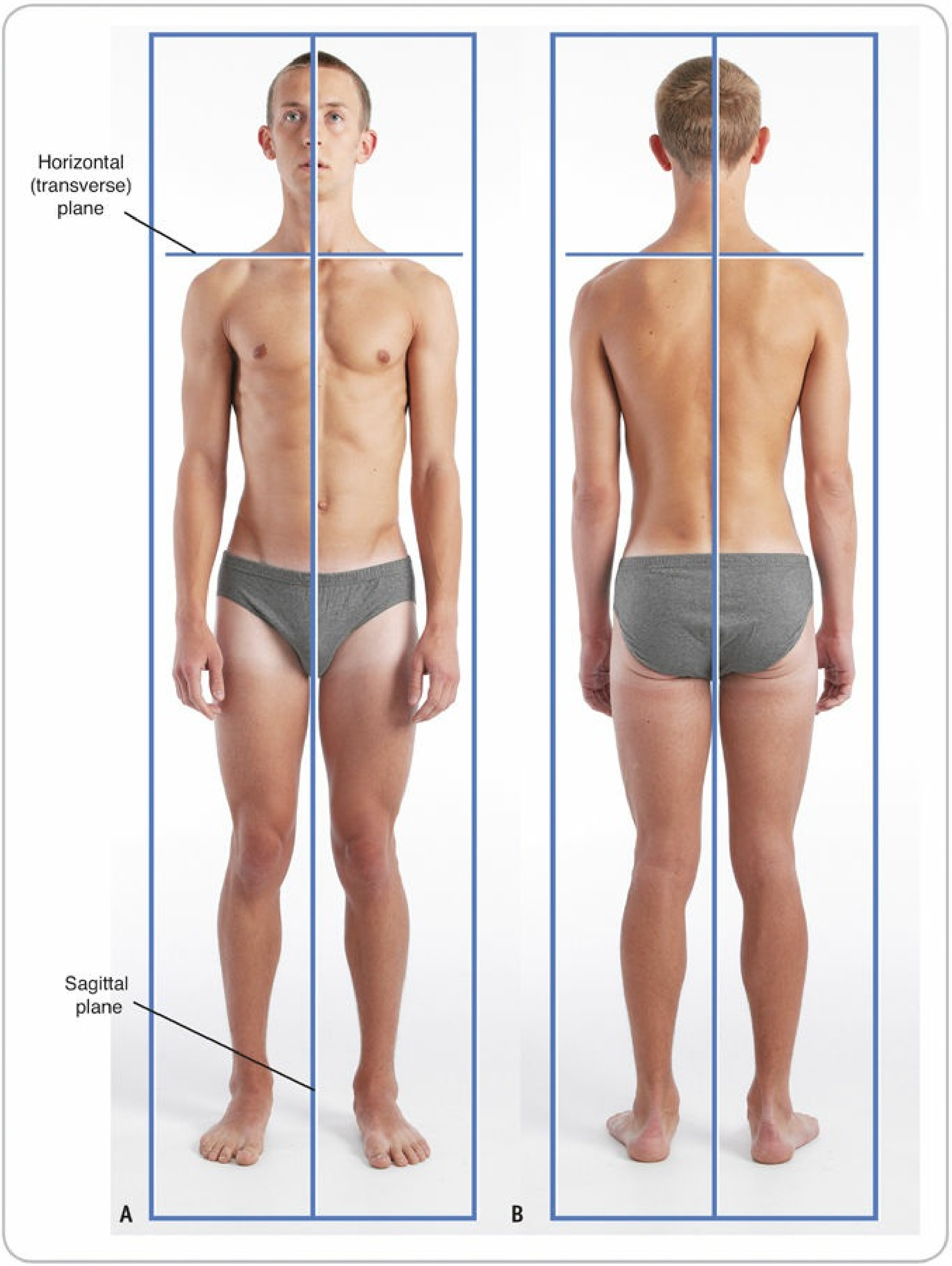

Figure 8.3. Postural assessment. Front (**A**) and back (**B**) views with midsagittal and horizontal (transverse) plane.

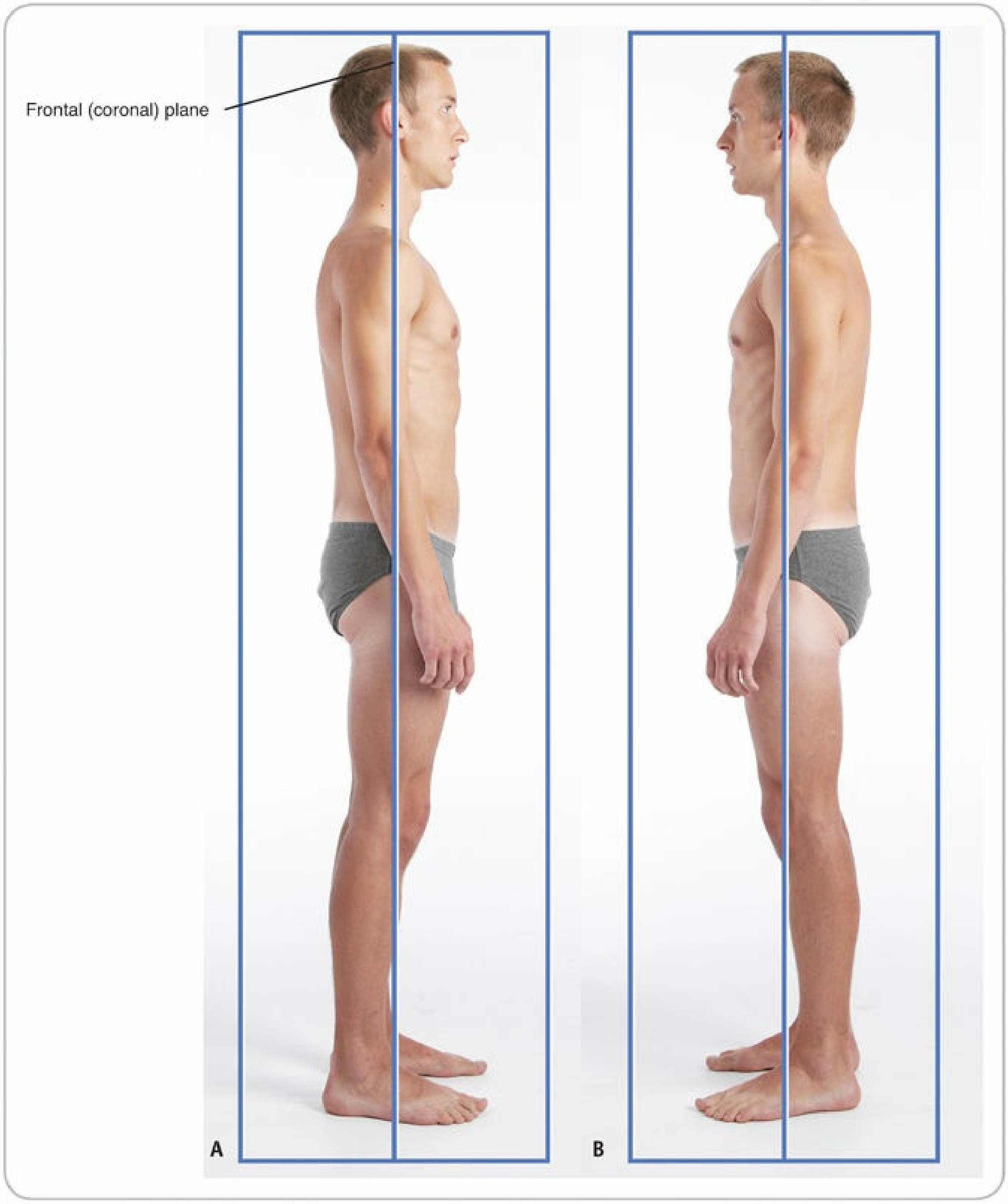

Figure 8.4. Postural assessment. Right and left side views with frontal (coronal) midline.

Deviations from Norm

As the clinician assesses postural alignment, it is common to view deviations. Postural deviations may result from mechanical stress derived from lateral spinal muscle imbalances or from sustaining repeated impact forces.[3] Often, these same forces result in back pain and/or injury. Excessive spinal curvatures can be congenital or acquired through weight training or sports participation. The most common deviations are lordosis, swayback, flat back, and kyphosis. These deviations can be observed from a lateral view. The one common deviation that can be viewed from the posterior view is scoliosis.

Lordosis

Lordosis increases the anterior lumbar curve from neutral when compared to normal or optimal posture. This increased anterior lumbar curve will cause the pelvis to move into an anterior tilt position (see **Fig. 16.13**). The rotations will cause the ASIS to move inferiorly and the ischial tuberosity to move superiorly. Lordosis is often associated with weakened abdominal muscles in combination with tight muscles, especially the hip flexors, tensor fasciae latae, and deep lumbar extensors. Normally, the pelvic angle is approximately 30° (see **Fig. 8.2**). With excessive lordosis, this angle can increase to 40° and can be accompanied by a mobile spine and anterior pelvic tilt (**Fig. 8.5A**). Other causes of lordosis include congenital spinal deformity, such as bilateral congenital hip dislocation, spondylolisthesis, compensatory action resulting from another deformity (e.g., kyphosis), hip flexion contractures, poor postural habits, and overtraining in sports requiring repeated lumbar hyperextension (e.g., gymnastics, figure skating, football linemen, javelin throwing, or swimming the butterfly stroke). Because lordosis places added compressive stress on the posterior elements of the spine, low back pain is a common symptom predisposing many individuals to low back injuries.

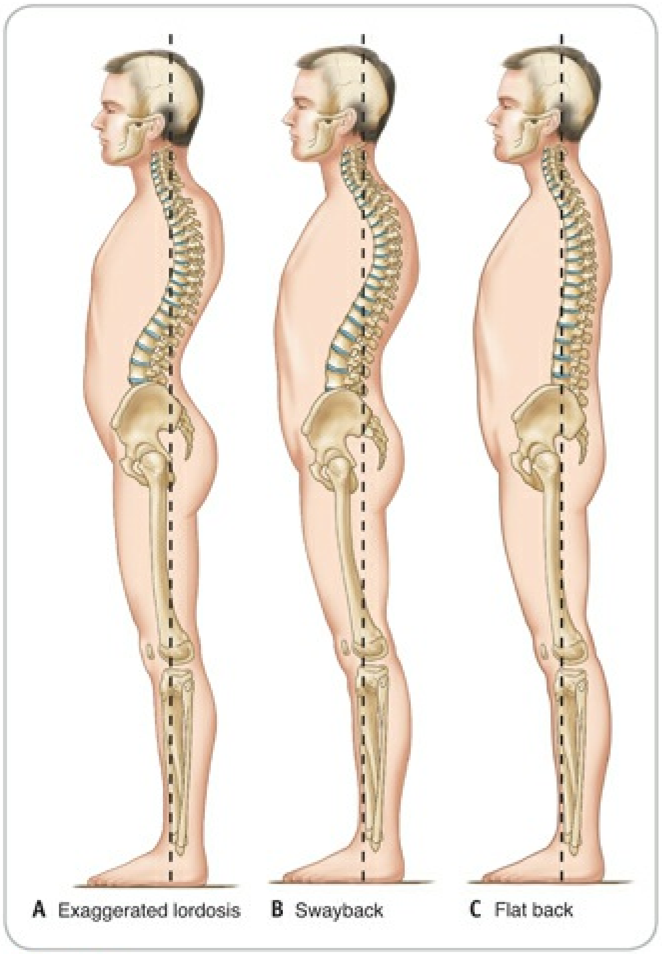

Figure 8.5. Lumbar anomalies. A, Lordosis. **B,** Swayback. **C,** Flat back.

Swayback

Swayback is a decrease of the anterior lumbar curve and increase in the posterior thoracic curve from neutral. This position causes the head and superior aspect to the femur to shift anterior in order to compensate for the posterior position. An individual with a swayback deformity (**Fig. 8.5B**) presents with an increased lordotic curve and kyphosis. This condition often results from weakness in the lower abdominals, lower thoracic extensors, hip flexors, compensatory tight hip extensors, lower lumbar extensors, and upper abdominals. The deformity results as the spine bends back sharply at the lumbosacral angle.[5] Subsequently, the entire pelvis shifts anteriorly, causing the hips to move into extension. For the center of gravity to remain in its normal position, the thoracic spine flexes on the lumbar spine, increasing the lumbar and thoracic curves.

Flat Back

Flat back is a decreased anterior lumbar curve. This curve typically causes the pelvis to rotate into the posterior pelvic rotation (see **Fig. 16.13**). With posterior pelvic rotation, the ASIS moves superiorly and the ischial tuberosity moves inferiorly. The term flat back refers to a relative decrease in lumbar lordosis (20°), which shifts the center of gravity anterior to the lumbar spine and hips (**Fig. 8.5C**).[3] The condition may result from the use of Harrington rods in the treatment of scoliosis, degenerative disk disease involving multiple levels of the spine, ankylosing spondylitis, and postlaminectomy syndrome compression fractures, most commonly caused by osteoporosis.

The most common clinical sign is the tendency to lean forward when walking or standing. In an effort to bring the body into better alignment, the low back, buttocks, and posterior thigh muscles are recruited to tilt the pelvis. This action causes these muscles to fatigue more quickly, leading to aching and pain. The body also may compensate by exhibiting increased hip and knee flexion. If hip flexion is accentuated, however, a hip flexion contracture may occur. Treatment involves strengthening the gluteal, low back, abdominal, and hamstring musculature.

Kyphosis

Kyphosis (**Fig. 8.6A**) is an increase in the posterior thoracic curve from neutral. This curvature will most likely cause an anterior head position, an increase in lordosis, and an anterior pelvic rotation. The cause of kyphosis can be congenital, idiopathic (unknown), or secondary to osteoporosis. Congenital kyphosis arises from deficits in the formation of either the vertebral bodies or the anterior and posterior vertebral elements. Idiopathic kyphosis, also known as **Scheuermann disease** or osteochondritis of the spine, is present in about 7% of the population and involves the development of one or more wedge-shaped vertebrae in the thoracic or lumbar regions through abnormal behavior of the epiphyseal plate.[6] The individual typically has a round-shouldered appearance, with or without back pain. Weight lifters, gymnasts, and football linemen, who overdevelop the pectoral muscles, also are prone to this condition. In addition, it may be caused by overtraining with the butterfly stroke, hence the nickname “swimmer’s back.”

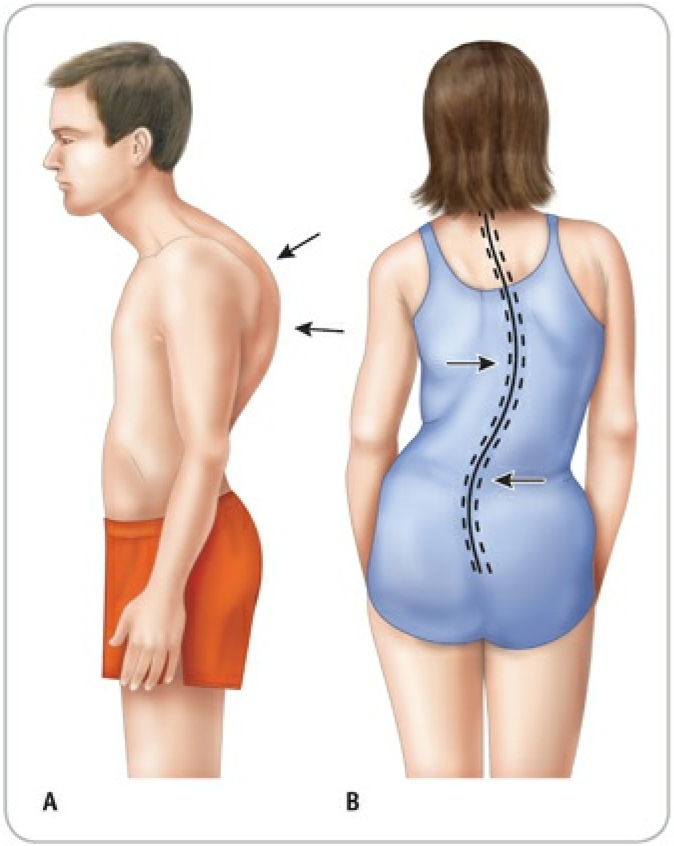

Figure 8.6. Faulty alignments of the thoracic region include kyphosis (A) and scoliosis (B).

Scoliosis

Scoliosis is a lateral curvature in the thoracic spine. The lateral curvature could cause bilateral asymmetries of the shoulder or pelvic area when viewing the patient from the anterior or posterior view.

Scoliosis is found in 2% to 3% of the population (Fig. 8.6B).[6] The lateral deformity, coupled with rotational deformity of the involved vertebrae, may range from mild to severe. Scoliosis may appear as either a C- or an S-shaped curve involving the thoracic spine, lumbar spine, or both. Scoliosis can be structural or nonstructural. Structural scoliosis involves an inflexible curvature that persists with lateral bending of the spine. Nonstructural scoliosis curves are flexible and are corrected with lateral bending. Although congenital abnormalities, certain cancers, and leg length discrepancy may lead to scoliosis, approximately 70% to 90% of all cases are idiopathic. Idiopathic scoliosis most commonly is diagnosed between the ages of 10 and 13 years but can be seen at any age and is more common in females.[6]

Symptoms associated with scoliosis vary with the severity of the condition. Mild cases (curvature <20°) usually are asymptomatic and self-limiting. If scoliosis presents during childhood, reassessment should occur every 3 to 4 months until the adolescent has skeletally matured. Active treatment is not necessary as long as the curve is nonprogressive. If the individual is skeletally immature and the curve is moderate (20° to 45°) and progressive, bracing is necessary. In many instances, the treatment allows enough time out of the brace for daily participation in sport and physical activity. In general, relatively unrestricted physical activity is recommended for almost all adolescents with scoliosis. Mild-to-moderate cases can be treated with strength, flexibility, and general fitness activities. Severe scoliosis, which is characterized by extreme lateral deviation and localized rotation of the spine, can be painful and deforming, and it may require surgery (fusion with spinal instrumentation).[6]

Cross Syndrome

There are two commonly seen postural syndromes whose characteristics have been described by Janda[7] from observation:

- Upper cross syndrome (UCS), also referred to as shoulder cross syndrome or proximal
- Lower cross syndrome (LCS), also referred to as pelvic cross syndrome or distal

In **upper cross syndrome**, tightness of the upper trapezius and levator scapula on the dorsal side crosses with tightness of the pectoralis major and minor (**Fig. 8.7**). Weakness of the deep cervical flexors ventrally crosses with weakness of the middle and lower trapezius. This pattern of imbalance creates joint dysfunction, particularly at the atlanto-occipital joint, C4–C5 segment, cervicothoracic joint, glenohumeral joint, and T4–T5 segment. Janda[7] noted that these focal areas of stress within the spine correspond to transitional zones in which neighboring vertebrae change in morphology. Specific postural changes are seen in UCS, including forward head posture, increased cervical lordosis and thoracic kyphosis, elevated and protracted shoulders, and rotation or abduction and winging of the scapulae. These postural changes decrease glenohumeral stability as the glenoid fossa becomes more vertical due to serratus anterior weakness leading to abduction, rotation, and winging of the scapulae. This loss of stability requires the levator scapula and upper trapezius to increase activation to maintain glenohumeral centration.[7]

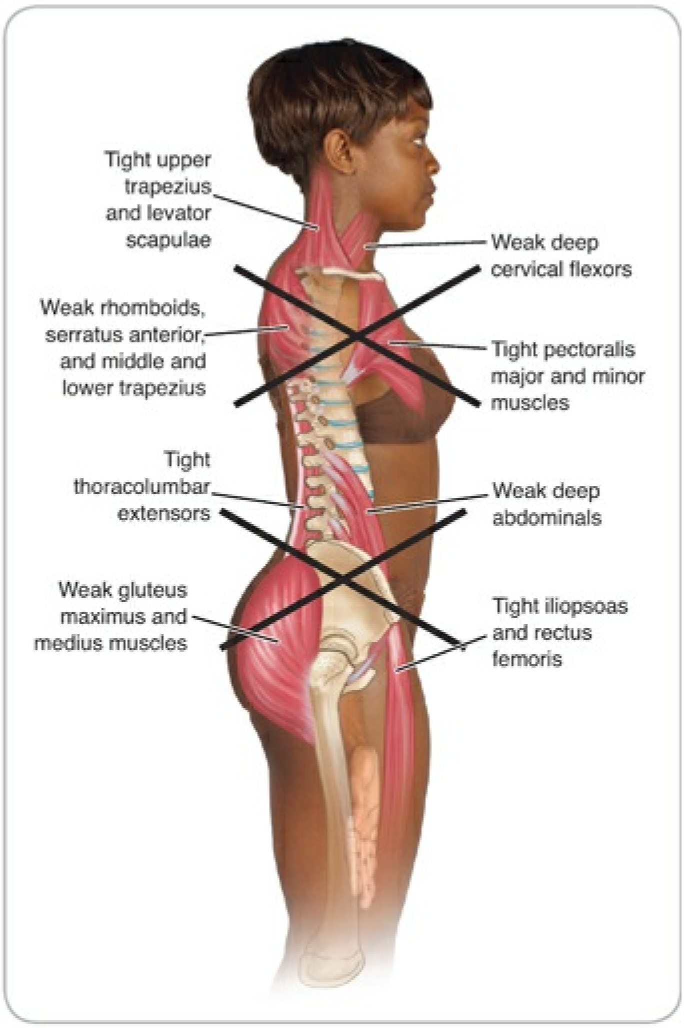

Figure 8.7. Muscle imbalance syndromes resulting in faulty posture include upper cross syndrome and lower cross syndrome.

Lower crossed syndrome, tightness of the thoracolumbar extensors on the dorsal side, crosses with tightness of the iliopsoas and rectus femoris. Weakness of the deep abdominal muscles ventrally crosses with weakness of the gluteus maximus and medius (see **Fig. 8.7**). This pattern of imbalance creates joint dysfunction, particularly at the L4–L5 and L5–S1 segments, sacroiliac (SI) joint, and hip joint. Specific postural changes seen in LCS include anterior pelvic tilt, increased lumbar lordosis, lateral lumbar shift, lateral leg rotation, and knee hyperextension. If the lordosis is deep and short, then imbalance is predominantly in the pelvic muscles; if the lordosis is shallow and extends into the thoracic area, then imbalance predominates in the trunk muscles.[7]

Assessing Flexibility and Muscle Length and Strength

Good posture and good body mechanics are linked. Good body mechanics depend on proper body alignment and muscle function such as strength, length, flexibility, and balance.[3] When considering body mechanics, the more flexibility present, there is less stability. The less flexible, the more stable the structure becomes. Therefore, assessing flexibility and muscle length and strength provides the clinician with potential causes of why faulty posture may be present and why the patient is experiencing pain or dysfunction. Assessing flexibility and muscle length and strength will be discussed in Chapters 14 to 22 in relation to specific parts of the body and specific pathologies.

> The lacrosse player appears to have normal posture except for a slight forward head position, mild increase in cervical lordosis, and thoracic kyphosis. This patient appears to have UCS, which would result in thoracic pain of unknown origin. Further testing revealed the patient has shortened and tight pectoral muscles. This patient will benefit from a program to strengthen the posterior thoracic muscles, lengthen the anterior thoracic muscles, and improve scapulothoracic rhythm as well as working on normal head positioning.

THE GAIT CYCLE

? A 26-year-old female patient presents with a history of recurrent and growing pain in her right hip but cannot identify an acute mechanism of injury. The patient began adding running to her exercise program about a year ago and feels that might have something to do with her pain. Inspection and palpation results are normal. How will conducting a gait assessment assist the clinician in determining the cause of the patient's pain?

Despite variation in individual gait patterns, enough commonality exists in human gaits that one can describe the typical gait cycle. Assessment of gait can provide the clinician clues regarding a patient's impairment and subsequent dysfunction. Postinjury, the clinician often uses gait training in the rehabilitation program for patients with lower extremity injury. In order to be able to teach a patient proper gait function, an understanding of the normal gait cycle is required. The gait cycle requires a set of coordinated, sequential joint actions of the lower extremity. This section describes the kinematics of the hip, knee, lower leg, ankle, and foot and identifies the muscles that are responsible for specific movements and potential causes of dysfunction.

Kinematics of the Lower Leg, Ankle, and Foot

Toe Flexion and Extension

Several muscles contribute to flexion of the second through fifth toes. These include the flexor digitorum longus, flexor digitorum brevis, quadratus plantae, lumbricals, and interossei. The flexor hallucis longus and brevis produce flexion of the hallux. Conversely, the extensor hallucis longus, extensor digitorum longus, and extensor digitorum brevis are responsible for extension and overextension of the toes.

Dorsiflexion and Plantar Flexion

Motion at the ankle occurs primarily in the sagittal plane, with ankle flexion and extension being termed dorsiflexion and plantar flexion, respectively (**Fig. 8.8A**). The medial and lateral malleoli serve as pulleys to channel the tendons of the leg muscles either posterior or anterior to the axis of rotation and, in doing so, enable their contributions to either plantar flexion or dorsiflexion. Muscles with tendons passing anterior to the malleoli (i.e., the tibialis anterior, extensor digitorum longus, and peroneus tertius) are dorsiflexors. Those with tendinous attachments running posterior to the malleoli contribute to plantar flexion. The major plantar flexors are the soleus, gastrocnemius, plantaris, and flexor hallucis longus, with assistance being provided by the peroneal longus and brevis and by the tibialis posterior.

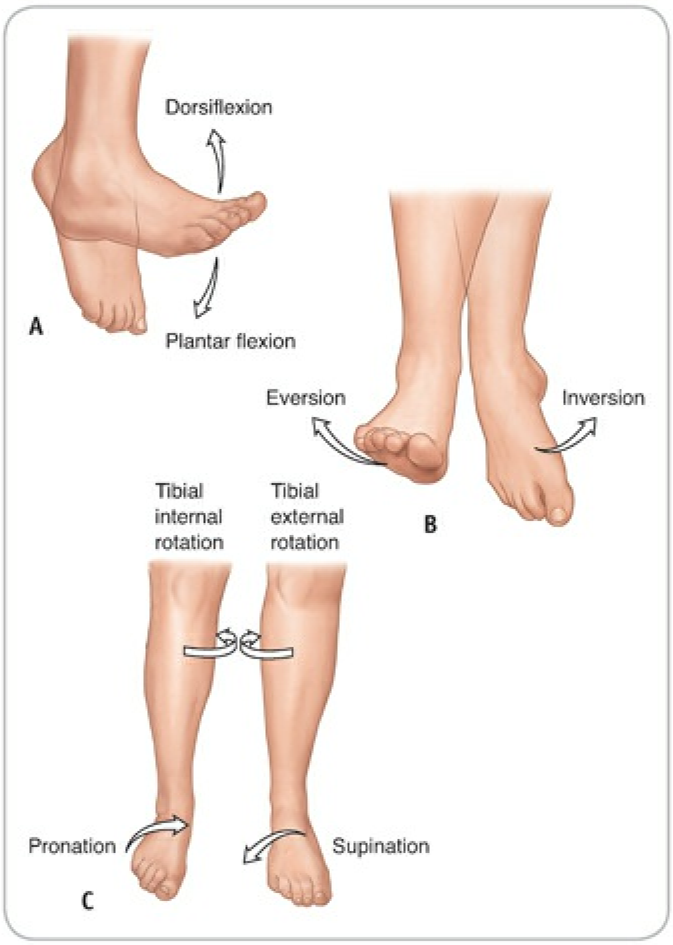

Figure 8.8. Motions of the foot and ankle. A, Dorsiflexion and plantar flexion. **B,** Eversion and inversion. **C,** Supination of the subtalar joint results in external rotation of the tibia; pronation is linked with internal rotation of the tibia.

Inversion and Eversion

Rotations of the foot in the medial and lateral directions are termed inversion and eversion, respectively (**Fig. 8.8B**). These movements occur primarily at the subtalar joint, with secondary contributions from gliding movements at the intertarsal and tarsometatarsal joints. The tibialis posterior is the major inverter, with the tibialis anterior providing a minor contribution. The peroneus longus and brevis, with tendons passing behind the lateral malleolus, are primarily responsible for eversion, with assistance being provided by the peroneus tertius.

Pronation and Supination

The lower extremity moves through a cyclical sequence of movements during gait. Among these, the action at the subtalar joint during weight bearing has the most significant implications for lower extremity injury potential. During heel contact, the hindfoot typically is somewhat inverted. As the foot rolls forward and the forefoot initially contacts the ground, the foot is plantar-flexed. This combination of calcaneal inversion, foot adduction, and plantar flexion is known as supination. During weight bearing at midstance, both calcaneal eversion and foot abduction tend to occur as the foot moves into dorsiflexion; these movements are known collectively as pronation. Supination of the subtalar joint also results in external rotation of the tibia, with pronation being linked to internal tibial rotation (**Fig. 8.8C**).

Although a normal amount of pronation is useful in reducing the peak forces sustained during impact, excessive or prolonged pronation can lead to several overuse injuries, including stress fractures of the second metatarsal and irritation of the sesamoid bones, plantar fasciitis, Achilles tendinitis, and medial tibial stress syndrome.[8] Normal walking gait typically involves approximately 6° to 8° pronation.

Kinetics of the Lower Leg, Ankle, and Foot

The lower extremity sustains not only the weight of the body but also the weight of any carried loads and the forces of foot impacts during gait as well. Because force is what ultimately causes injury, understanding the kinetic aspects of lower leg, ankle, and foot function is an important foundation for understanding injury mechanisms.

Forces Commonly Sustained by the Lower Leg, Ankle, and Foot

During training, the bones of the lower extremity are subjected to a complex array of loading patterns, including tension, compression, bending, and torsion. During running, the foot sustains impact forces that can reach two- to threefold body weight, and the magnitudes of the forces increase with gait speed. Running-related injuries occur in 40% to 50% of runners annually, with cavus feet and leg length inequality being documented risk factors.[9]

Foot Deformation During Gait

The structures of the foot are anatomically linked, with approximately 50% of body weight distributed through the subtalar joint to the calcaneus, and the remaining 50% channeled through the transverse tarsal joints to the forefoot.[10] Plantar pressure distribution is affected by gender, shoe type, support surface, and fatigue as well as by individual foot conformation and gait characteristics.[2,11,12]

If the foot were a more rigid structure, each impact with the support surface would generate extremely large forces of short duration through the skeletal system. Because the foot is composed of numerous bones that are connected by flexible ligaments and are restrained by flexible tendons, it deforms with each ground contact. In doing so, it absorbs much of the shock and transmits a much smaller force of longer duration up through the skeletal system.

The process of foot deformation during weight bearing results in the storage of mechanical energy in the stretched tendons, ligaments, and plantar fasciae. As the tibia rotates forward over the talus during gait, additional energy is stored in the gastrocnemius and soleus as they develop eccentric tension. During the push-off phase, the stored energy in all these elastic structures is released, contributing to the force of push-off and actually reducing the metabolic energy cost of walking or running.

Kinetics of the Knee

Because the knee is positioned between the body's two longest bony levers (i.e., the femur and the tibia), the potential for torque and force development at the knee is significant. The key role played by the knee during weight bearing makes the knee subject to large forces during the gait cycle.

Forces at the Tibiofemoral Joints

Weight bearing and tension development in muscles crossing the knee are the predominant forces acting at the tibiofemoral joints, with both contributing to joint compression. The medial compartment sustains the majority of the load during stance, with compressive force at the joint reaching an estimated threefold body weight during the stance phase of gait, increasing to around three- to sixfold body weight during stair climbing.[13,14] Comparison of front and back squat exercises shows significantly higher knee compressive forces during the back squat as compared to the front squat, with shear forces at the knee during squat exercises being small and posteriorly directed.[15] During sport participation, knee forces undoubtedly are large, although quantitative estimates are lacking. Tension in the knee extensors also increases lateral stability of the knee, with tension in the knee flexors contributing to medial stability.

Forces at the Patellofemoral Joint

Compressive force at the patellofemoral joint has been found to be half the body weight during normal walking gait, increasing up to eightfold body weight during stair climbing.[14] During stair climbing, there is an increase in patellofemoral pressure, lateral force distribution, and lateral patellar tilt.[16]

Knee Motion During the Gait

During midstance of normal gait, the knee is flexed to approximately 20°, internally rotated approximately 5°, and slightly abducted. Knee motion during the swing phase includes approximately 70° of flexion, 15° of external rotation, and 5° of adduction.

Patellofemoral Joint Motion

During movements of knee flexion and extension, the patella glides in the trochlear groove, primarily in a vertical direction, with an excursion of as much as 8 cm. When the knee is fully extended, the inferior pole of the patella rests on the distal portion of the femoral shaft, just proximal to the femoral groove. During flexion, the patella makes initial contact with the groove at 10° to 20° of flexion, and it becomes seated within the groove as the knee approaches 20° to 30°. In this position, the lateral border of the trochlea is prominent, forming a barrier against lateral displacement of the patella. The inferior border of the patella tilts upward and medially during knee flexion, with the contact area increasingly shifted superiorly on the medial and lateral facets of the posterior patella.[17,18] The patella also undergoes medial and lateral displacement as the tibia is rotated laterally and medially, respectively, with the center of the patella following a circular path during knee flexion/extension.[19]

Kinematics and Major Muscle Actions of the Hip

Because the hip is a ball-and-socket joint, the femur can move in all planes of motion. However, the massive muscles crossing the hip tend to limit ROM particularly in the posterior direction.

Flexion

The major hip flexors are the iliacus and psoas major, which because of their common attachment at the femur are referred to jointly as the iliopsoas. Four other muscles cross the anterior aspect of the hip to contribute to hip flexion—namely, the pectineus, the rectus femoris, the sartorius, and the tensor fascia latae. Because the rectus femoris is a two-joint muscle that is active during both hip flexion and knee extension, it functions more effectively as a hip flexor when the knee is in flexion, as occurs when a person kicks a ball. The sartorius also is a two-joint muscle. Crossing from the ASIS to the medial surface of the proximal tibia just below the tuberosity, the sartorius is the longest muscle in the body.

Extension

The hip extensors are the gluteus maximus and the three hamstrings—namely, the biceps femoris, the semitendinosus, and the semimembranosus. The gluteus maximus usually is active only when the hip is in flexion, as occurs during stair climbing or cycling, or when extension at the hip is resisted. The nickname “hamstrings” derives from the prominent tendons of the three muscles, which are readily palpable on the posterior aspect of the knee. The hamstrings cross both the hip and the knee, contributing to hip extension and knee flexion.

Abduction

The gluteus medius is the major abductor at the hip, with assistance from the gluteus minimus. The hip abductors are active in stabilizing the pelvis during single-leg support of the body and during the support phase of walking and running. For example, when body weight is supported by the right foot during walking, the right hip abductors contract isometrically and eccentrically to prevent the left side of the pelvis from being pulled downward by the weight of the swinging left leg. This allows the left leg to move freely through the swing phase without scuffing the toes. If the hip abductors are too weak to perform this function, lateral pelvic tilt occurs with every step.

Adduction

The hip adductors include the adductor longus, adductor brevis, and adductor magnus. These muscles are active during the swing phase of gait, bringing the foot beneath the body’s center of gravity for placement during the support phase. The relatively weak gracilis assists with hip adduction. The hip adductors also contribute to flexion and internal rotation at the hip, especially when the femur is externally rotated. Strength and flexibility deficits in the hip adductors have been linked to increased risk of injury among ice hockey and soccer players.[20]

Medial and Lateral Rotation of the Femur

Although several muscles contribute to lateral rotation of the femur, six function solely as lateral rotators. These six muscles are the piriformis, gemellus superior, gemellus inferior, obturator internus, obturator externus, and quadratus femoris. The femur of the swinging leg rotates laterally to accommodate the lateral rotation of the pelvis during the stride.

The major medial rotator of the femur is the gluteus minimus, with assistance from the tensor fascia latae, semitendinosus, semimembranosus, gluteus medius, and the four adductor muscles. The medial rotators are relatively weak; their estimated strength is approximately one-third that of the lateral rotators.

Kinetics of the Hip

Forces at the Hip During Standing

The hip is a major weight-bearing joint that is subject to extremely high loads during sport participation. During upright standing, with weight evenly distributed on both legs, the weight supported at each hip is half the weight of the body segments above the hip. The total load on each hip in this situation is greater than the weight that is being supported, however, because tension in the large, strong hip muscles further adds to compression at the joint.

Forces at the Hip During Gait

Compression on the hip is approximately the same as body weight during the swing phase of normal walking gait but increases up to three- to sixfold the body weight during the stance phase.[21] Body weight, impact forces translated upward through the skeleton from the foot, and muscle tension contribute to this compressive load. Walking or running increases the forces on the hip. Use of a crutch or a cane on the side opposite an injured lower limb serves to more evenly distribute the load between the legs throughout the gait cycle. It is better to use no assistive device than to use a crutch or a cane on the same side as the lower extremity injury because this actually increases joint forces on the injured side.[20]

The hip and lower extremity is part of a kinetic chain that transfers forces from the ground to body. Each joint within this chain is a link that must function smoothly and effectively to produce an efficient and pain-free gait. By performing a gait assessment, the clinician will be able to determine if the patient has normal muscle and joint function of each link in the kinetic chain that are responsible for walking and running. If dysfunction is found, the location and type of dysfunction will assist the clinician in determining if it is the related to or even the cause of the patient's hip pain.

GAIT ASSESSMENT

? The 26-year-old female patient presented with a history of recurrent and growing pain in her right hip but could not identify an acute mechanism of injury. The patient began adding running to her exercise program about a year ago and feels that might have something to do with her pain. How will the athletic trainer determine what is a normal gait for this patient and, if the gait is altered, what factors could contribute to her pathology?

The gait cycle (**Fig. 8.9**) begins with a period of single-leg support in which body weight is supported by one leg while the other leg swings forward. The swing phase can be divided into the initial swing, midswing, and terminal swing. The period of double support begins with the contact of the swing leg with the ground or floor. As body weight transfers from the support leg to the swing leg, the swing leg undergoes a loading response and becomes the new support leg. A new period of single support then begins as the swing leg loses ground contact. The time during which body weight is balanced over the support leg is referred to as midstance. As the body's center of gravity shifts forward, the terminal stance phase of the support leg coincides with the terminal swing phase of the opposite leg.

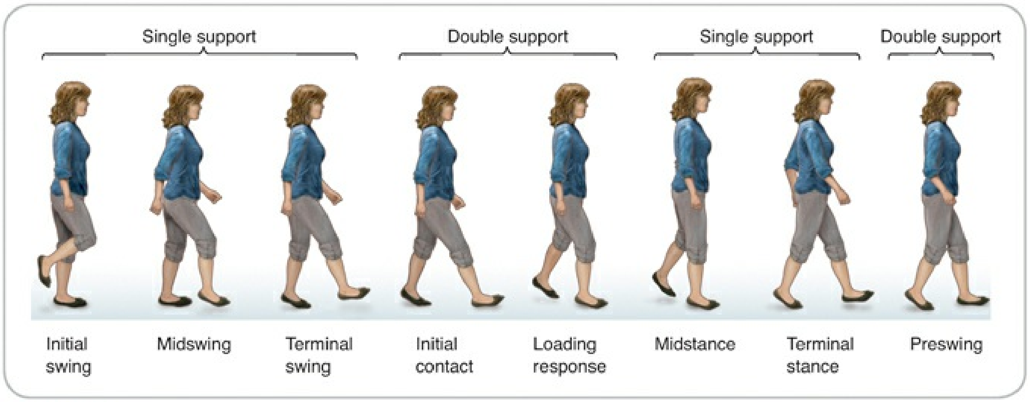

Figure 8.9. Gait. The gait cycle consists of alternating periods of single-leg support and double-leg support.

Differences in running gait have been documented based on both gender and age. Among recreational runners, females appear to have greater hip adduction, hip internal rotation, and knee abduction compared to males.[8] A study of elite master sprinters showed an age-related decline in running speed related to reduction in stride length and increase in ground contact time.[9]

The lower extremity is dedicated to the task of weight bearing and ambulation or stance and swing. The health of all aspects of the lower extremity is critical to normal and efficient activities of daily living. Because pathology that affects the lower extremity often provides the practitioner with a visual clue, it is critical to understand normal and abnormal patterns of ambulation so that the athletic trainer can recognize and treat pathologies quickly. Specific terminology used to describe the components of the gait assessment is presented in **Table 8.1**.

TABLE 8.1 Gait Terminology

TERM	DEFINITION
Arm swing	Amplitude and frequency with which the arm is moved during gait
Cadence	How fast one walks: number of steps per minute
Foot angle	Angle between line from heel to second toe and line of direction
Forward lean	Leading with torso in front of pelvis
Forward pelvis	Leading with pelvis in front of torso
Pelvic list	Up and down motion of pelvis
Pelvic sway	Side-to-side motion of pelvis
Stance phase	Time spent in weight bearing or in contact with the ground
Step	Sequence of events from a specific point in the gait on one extremity to the same point in the opposite extremity
Step length	Distance traveled between the initial contacts of the right and left foot
Step width	Distance between the points of contact of both feet
Stride	Two sequential steps
Stride length	Linear distance covered in one stride
Stride time	Time required to complete a single stride
Torso swing	Rotational movement of torso

There are two phases to normal walking cycle: stance phase and swing phase. Stance phase is when the foot is on the ground. Swing phase is when the foot is moving forward. Sixty percent of the normal cycle is spent in stance phase (25% of which is spent in double stance) and 40% in swing phase. Each phase is then divided into its smaller components in the following section.

Basic Gait Cycle

The gait cycle is composed of two phases, with eight components (Fig. 8.10).

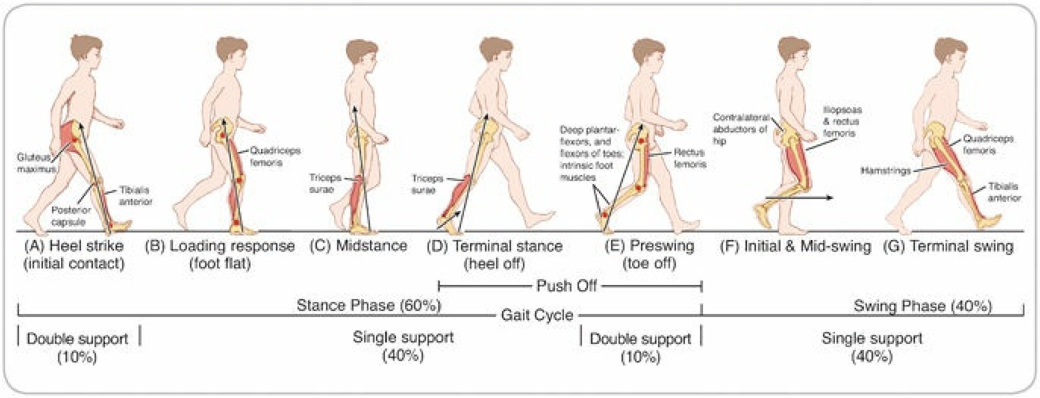

Figure 8.10. **Gait cycle: Stance and swing phase.** The activity of one limb between two repeated events of walking. Eight phases are typically described, two of which have been combined in (F) for simplification.

Stance Phase

Body weight is shifted to a single limb as the contralateral limb is in the swing phase and swings through. Subcomponents of this include the following:

- Initial contact (heel strike)
  - The mechanical goals of the heel strike are to lower the forefoot to the ground, continue deceleration (reverse forward swing), and to preserve the longitudinal arch of the foot.
- Loading response (flat foot)
- Midstance
- Terminal stance (heel off)
- Preswing phase (toe off): Preswing coincides with initial contact of opposite limb and is the only point in the gait cycle where double limb support occurs. The primary function of this phase of gait is to position the limb in preparation for the swing.

Swing Phase

Swing phase is composed of the initial swing (acceleration), midswing, and terminal swing (deceleration).

- Initial swing starts as the foot is lifted from contact with the ground and continues until the foot of the moving limb is aligned with the foot of the nonmoving limb.
- Midswing is a continuation of the initial swing, moving the foot from parallel with the foot of nonmoving limb forward into almost full knee extension.
- Terminal swing occurs when the knee is in full extension and initial contact is about to happen.

Assessing Gait

The patient is instructed to wear clothing such as midthigh length shorts and a loose but not overly large fitting shirt that will allow the clinician to observe muscle and joint function of the lower extremity. Socks and shoes should not been worn during initial assessment. However, the assessment can be repeated later with the patient wearing shoes for comparison of findings. Identify a walking path that is free from obstacles and long enough to allow the patient to assume a normal walking pace before having to turn around. The athletic trainer will need to observe the patient from an anterior and posterior view as well as a lateral view (right and left). The athletic trainer may need to ask the patient to walk back and forth for several minutes while focusing on different parts of the gait. At times, the athletic trainer may need to kneel down to get the correct perspective of foot motion. Table 8.2 is a checklist that can be used during gait assessment.

TABLE 8.2 Checklist for Gait Assessment

ITEM	FINDINGS: ANTERIOR VIEW	FINDINGS: POSTERIOR VIEW	FINDINGS: LATERAL VIEW
Initial contact			
Loading response			
Midstance			
Terminal stance			
Preswing			
Initial swing			
Midswing			
Terminal swing			
Stride length			
Step length			
Stride width			
Pelvic list			
Pelvic sway			
Torso movement			
Arm swing			
Weight-bearing sequence			
Non–weight-bearing sequence			
Cadence			
Circle if present; indicate right/left.	Gluteus maximus gait Trendelenburg gait Psoatic gait	Stiff knee gait Steppage or drop foot gait Short leg gait	Calcaneal gait

Los Amigos Research & Education Center. *Observational Gait Analysis-Revised.* Downey, CA: Los Amigos Research & Education Center; 2013.

Observe the following normative findings:

a. The width of the normal base (step width) measures from 2 to 4 in and the normal step is from heel to heel. Note if the patient is walking with a wider base. This may indicate a possible pathology. Patients usually widen their base if they are on an unstable surface or feel dizzy, such as a patient who sustained a concussion. A patient could also widen the normal base of support if he or she is suffering from a decreased sensation in the sole of the foot. Normal step length is approximately 15 in. Step length can be affected by muscle contraction, walking on an unstable surface, or other balance and neuromuscular control pathologies. Step width and step length is depicted in **Figure 8.11**

b. Center of gravity: The body's center of gravity lies 2 in in front of the second sacral vertebra. In normal gait, the body oscillates no more than 2 in in a vertical direction. A smooth pattern of gait as the body advances forward indicates controlled vertical oscillations.

c. The knee should remain flexed during all components of the stance phase except for initial contact to prevent the excessive vertical displacement of the center of gravity.

d. The pelvis and truck shift laterally approximately 1 in to the weight-bearing side during gait to center the weight over the hip.

e. The average length of a step is approximately 15 in, and the average adult walks at a cadence of approximately 90 to 120 steps per minute.

f. During the swing phase, the pelvis rotates 40° forward, whereas the hip joint on the opposite extremity acts as the fulcrum for rotation.

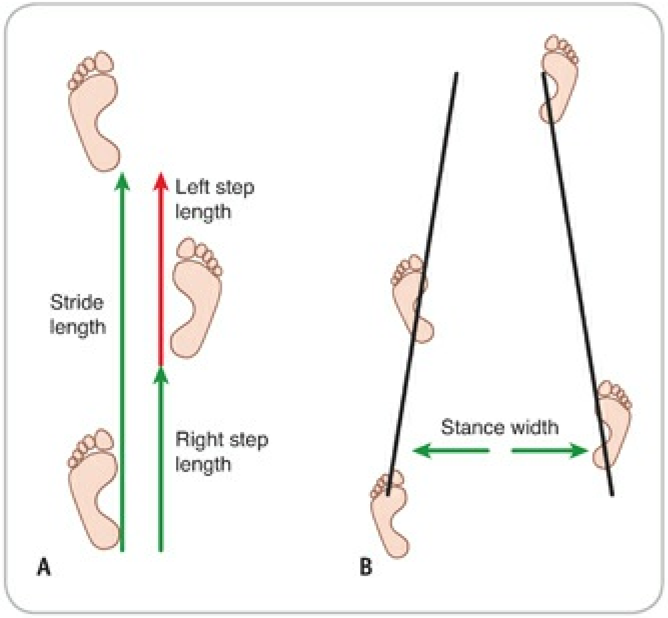

Figure 8.11. Stride length and stance width. A, One stride length is equal to the sum of on right and left step length. **B, Stance width.** The effect of acceleration on stance width is gradual reduction as the individual gets upright and into his or her stride.

Assessing Gait in Elderly Patients

When assessing gait in elderly patients or patients with neurocognitive deficits, additional precautions are needed. Begin the evaluation with a general neurological test looking at cranial nerve function (including visual fields and acuity) and cerebellar function (heel to shin, Romberg) and assess the peripheral nervous systems. Pay particular attention to normal/abnormal foot sensation, proprioception (great toe position sense, 10-g monofilament, vibratory), and overall muscle function. The athletic trainer should also look for musculoskeletal abnormalities and deformities, particularly of the foot and lower extremities and the spine.

Standing and balance

- Observe how the patient rises. Do they need to use their arms to push off, or do you notice any balance problems in rising from the chair? When they stand, is it done with or without support? Ask the patient to stand with his or her eyes closed and turn 360°.

Walking

- Observe how the patient begins to walk (i.e., hesitancy or multiple attempts). Notice the step height for both feet, foot clearance (looking for foot drop), step symmetry between right and left sides, and the speed of the gait.
- Look for signs of path deviation and the need to use adaptive equipment to maintain a straight path. Observe the posture and trunk for evidence of swaying, flexion, arm swing, and stability.
- Assess tandem and heel-walking gaits.

Endurance

- Observe the patient for any signs of fatigue or for comorbid problems that compromise walking.

The Timed Get Up and Go Test (TGUAGT) is one of the most commonly used tests to assess healthy adults for risk of falling through assessment of gait and balance.[22] The TGUAGT begins by observing the patient rising from the chair to a standing position. The patient walks at his or her usual pace 3 m (approximately 10 ft), turns around, walks back to the chair, and sits down. Patients are allowed to use their walking assists, such as canes, if normally used in everyday life. However, patients are instructed *not* to use their arms as an assist in rising from the chair. Performing this test in less than 20 seconds indicates that the individual is independent for transfers and mobility, whereas times greater than 30 seconds suggests increased risk for falls and dependence.[22]

Causes of Altered Gait Patterns

Most altered gait patterns occur during the stance phase as the patient responds to pain or dysfunction. When a patient alters his or her gait to alleviate pain, the patient is said to walk with an **antalgic gait**, or limp. The patient will remain on the involved extremity for as short a time as possible. Additional causes for altering gait, such as nerve damage, are presented in Table 8.3.

TABLE 8.3 Abnormal Gait Patterns		
TERM	DESCRIPTION	CAUSE
Stiff knee or hip gait	The patient will lift the knee of the involved side higher than normal to clear the ground due to knee or hip stiffness.	Associated with stiffness, laxity, or pain in knee or hip
Equine gait	The patient will bear weight primarily on the lateral edge of foot with no heel strike on initial contact.	Associated with congenital condition where Achilles tendon is shortened
Trendelenburg gait	The patient will thrust the thorax laterally to keep the center of gravity over the weight-bearing leg.	Associated weak gluteus medius muscle
Psoatic limp	The patient will have difficulty swinging leg through, and trunk movement is exaggerated.	Associated with hip conditions such as Legg-Calvé-Perthes disease. Look for this in adolescent patients.
Quadriceps gait	The patient will use trunk to swing leg forward and push off with toes instead of flexing and extending at knee.	Associated with injury to quadriceps muscle
Short leg gait	The patient will shift from side to side.	Associated with leg length difference due to skeletal shortening of one leg
Drop foot gait	The patient will lift knee higher to allow the foot to clear ground. Foot often slaps when it lands on ground.	Associated with weak dorsiflexors or anterior compartment syndrome

Initial Contact

If the patient is complaining of foot pain, it could be a result of heel pathology, such as a heel spur or a calcaneal fat pad contusion. To relieve the pain, the patient might try to hop onto the involved foot in an attempt to avoid heel strike completely or may attempt to strike with the midfoot or on the toes. The knee is normally extended during initial contact. If the patient is unable to extend the knee, it could be a result of weak quadriceps, an extension lag from a past injury, acute inflammation, or patellofemoral pathology.

Loading Response

The dorsiflexors of the foot permit the foot to move in to plantar flexion through eccentric elongation so that the foot flattens smoothly on the ground. Patients with weak or nonfunctioning dorsiflexors may slap the foot down after heel strike (**drop foot**) instead of letting it land smoothly. Patients who suffer from posterior tibial tendinopathy will also struggle with the foot flat stage as the muscle is eccentrically loaded to decelerate the foot. The patient will have pain and shift his or her weight to the lateral aspect of the foot.

Midstance

During the midstance phase, weight is normally borne evenly on all aspects of the foot. Patients with rigid pes planus, pes cavus, or subtalar arthritis may develop pain when walking on uneven ground. Pain may appear on the medical aspect of the lower leg or foot for a patient who has pes planus. Patients who have pes cavus may have pain on the lateral aspect of the foot or lower leg due to the weight bearing being shifted in a lateral direction. Patients who suffer from fallen transverse arches of the forefoot may develop painful calluses over the metatarsal heads. During midstance, if the gluteus medius muscles are weak, the patient will tend to lurch forward to the involved side to place the center of gravity over the hip.

Preswing

Patients with turf toe or **hallux rigidus** of the metatarsophalangeal joint may be unwilling or unable to hyperextend the metatarsophalangeal joint of the great toe. The lack of great toe extension may force the patient to push off from the lateral side of his or her forefoot. This shift in gait will eventually lead to pain and dysfunction. **Metatarsalgia** or **interdigital neuromas** could also cause the patient to not want to toe off leading to a lateral shift to compensate.

Acceleration

The dorsiflexors of the ankle are active during the entire swing phase by shortening the extremity so that it can clear the ground by holding the ankle in a neutral position. If the patient suffers from drop foot, this will cause the patient to hip the hike in order to assist with having the foot clear the ground. The knee also serves to shorten the extremity with maximum knee flexion approximately 65°. Patients who cannot obtain an adequate amount of flexion to allow the foot to clear the ground will have a shorten stride length or will lean the torso to the opposite site in an attempt to elevate the hip.

Midswing

If the ankle dorsiflexors are not working to keep the ankle in neutral, the tip of the toe will scrap the ground and produce a character shoe scrape. To compensate, the patient may flex his or her hip excessively to bend the knee, permitting the foot to clear the ground. This gait is referred to as the **steppage**

gait and may be due to paralysis of the anterior tibial and fibular muscles and is seen in lesions of the lower motor neuron, such as multiple neuritis, lesions of the anterior motor horn cells, and lesions of the cauda equina.

Deceleration

The hamstring muscles contract to slow down the leg just prior to heel strike. This deceleration allows the heel to strike the ground in a controlled manner. If the hamstrings are weak or injured, the initial contact may be excessively harsh, causing thickening of the heel pad.

Although gait assessment is an essential tool for the practitioner, it is only part of the diagnostic process. It is critical to match the findings of the gait assessment to the history obtained from the patient. Realize that not every deviation from the norm is relevant to the patient's pathology.

> Gait assessment reveals on initial contact that the patient has very limited heel strike and that initial contact is being made on the lateral aspect of the midfoot on the same limb as her painful hip. During the swing phase, the patient does not fully extend the knee and walks with a forward lean. The clinician concludes the patient has a shortened Achilles tendon and tight hamstrings as well as tight hip flexors, which is resulting in poor running biomechanics. These factors may be placing additional stress on her hip.

SUMMARY

1. Prior to beginning an assessment of posture or gait, it is important to note the overall body appearance. Somatotyping categorizes the human body according to the three types: endomorph, mesomorph, and ectomorph.
2. Although there are some people who are purely ectomorphs, endomorphs, or mesomorphs with little or no characteristics of the other body types, very frequently, people fall into mixed categories, such as ecto-mesomorphs or endo-mesomorphs.

3. Optimal posture implies balanced dissemination of body mass around the center of gravity, where the compression forces on spinal disks are balanced by ligamentous tension and with minimal energy expenditure from postural muscles. Joint ROM and muscle length and strength also play a major role in achieving optimal posture.
4. Assessment of posture involves comparing alignment between the left and right and anterior and posterior aspects of the body along the line of the center of gravity. Observations made from the anterior, posterior, and lateral aspect will assist the clinician in detecting deviations from optimal posture positions.
5. Postural deviations may result from mechanical stress derived from lateral spinal muscle imbalances or from sustaining repeated impact forces. Often, these same forces result in back pain and/or injury. Excessive spinal curvatures can be congenital or acquired through weight training or sports participation.
6. The most common deviations are lordosis, swayback, flat back, and kyphosis.
7. Muscular imbalances developed through excessive or incorrect training techniques, overuse, and repetitive motion can lead to cross syndrome, a common cause of faulty posture.
8. Assessment of gait can provide the clinician clues regarding a patient's impairment and subsequent dysfunction. Postinjury, the clinician often utilizes gait training in the rehabilitation program for patients with lower extremity injury.
9. The gait cycle requires a set of coordinated, sequential joint actions of the lower extremity. Each joint within the lower extremity functions like a link in a chain. Each link must work efficiently in order for smooth and efficient gait to occur. Dysfunction can be caused by muscular imbalances, injury, improper tissue healing, injury, and swelling.
10. The gait is divided into two sections: stance phase and swing phase. The

stance phase is further divided into the initial contact, loading response, midstance, and terminal stance. The swing phase is further divided into the preswing, midswing, and terminal swing.

11. Gait is assessed from the lateral, anterior, and posterior aspect to detect quality of gait.
12. Most altered gait patterns occur during the stance phase as the patient responds to pain or dysfunction. When a patient alters his or her gait to elevate pain, the patient is said to walk with an antalgic gait, or limp. Gait patterns are also altered due to dysfunction, such as a weak gluteus medius muscle.
13. When assessing gait in elderly patients, additional testing is done prior to gait analysis to determine if assessment is appropriate and safe to perform.

APPLICATION QUESTIONS

1. It's peewee football season and the coaches are trying to determine how to match up players safely. Using somatotyping terminology and concepts, describe what considerations should be examined when setting up pairings.
2. A 25-year-old information technologist complains of nagging, constant pain in the midthoracic region with no history of trauma or illness. How might this person's job contribute to his pain?
3. As part of the preparticipation screening process, all student athletes will be screened for posture. Describe the most efficient way to set up the postural assessment screening station and identify the materials needed for the station to run smoothly.
4. What injuries might a 16-year-old male football athlete with a flat back be at higher risk of sustaining than his counterpart who has normal posture?
5. Your postural assessment suggests that your 18-year-old patient has

swayback. In order to determine the cause of the condition, which muscles will you assess and why?

6. Your patient presents with a history of tibial stress fractures over a 6-year period, corresponding with when she began running regularly. Analysis of running routine, surface, footwear, and diet does not help to identify a cause for the recurrent stress fractures. What information might be gathered through a combined postural and gait assessment that may help you in identifying a potential cause of her recurrent stress fractures?
7. How might a patient with repetitive hamstring strain present during a gait assessment during a time of noninjury?

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