

Normal Gait

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Walking is moving from place to place on your feet, and *gait* is the style or manner of walking. Each person has a unique style, and this style may change slightly with mood. When you are happy, your step is lighter, and there may be a “bounce” in your walk. Conversely, when sad or depressed, your step may be heavy. For some people, their walking pattern is so unique that they can be identified from a distance even before their face can clearly be seen. Regardless of the numerous different styles, the components of normal gait are the same.

In the most basic sense, walking requires balancing on one leg while the other leg is moved forward. This requires movement not only of the legs but also of the trunk and arms as well. To analyze gait, you must first determine what joint motions occur. Then, based upon that information, you must decide which muscles or muscle groups are acting.

Definitions

Certain definitions must be made to describe gait. **Gait cycle** is the activity that occurs between the time the heel of one extremity touches the floor and the time the same foot touches the floor again (Fig. 20-1). In other words, it occurs between the heel strike of the right leg and the heel strike of the right leg again, including all of the activity in between. The same definition could be given using the left leg. A

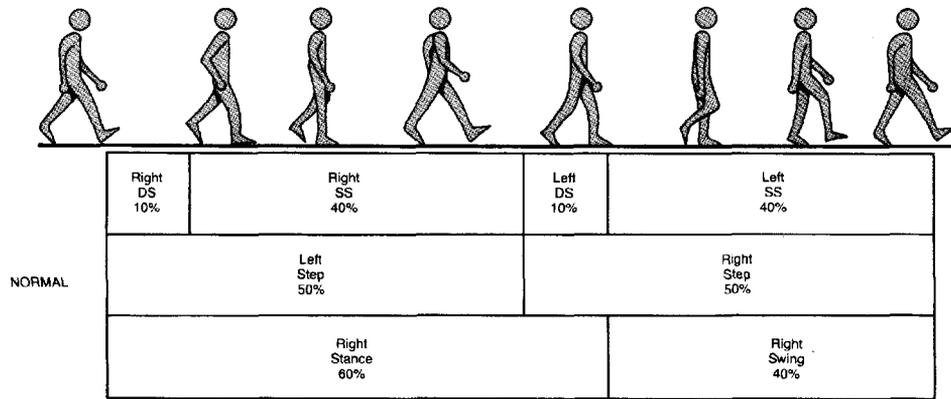


FIGURE 20-1. Phases of the gait cycle. Percentages are approximate and depend on walking speed, (DS = double support; SS = single support). (From Rothstein, JM, Roy, SH, and Wolf, SL: *The Rehabilitation Specialist's Handbook*. FA Davis, Philadelphia, 1991, p 700, with permission.)

stride length is the distance of the gait cycle; that is, the distance between heel strike of one leg and its subsequent heel strike (Fig. 20-2).

Stance phase is the activity that occurs when the foot is in contact with the ground. It begins with heel strike of one foot and ends when that foot leaves the ground. This phase accounts for about 60 percent of the gait cycle (Fig. 20-3). **Swing phase** occurs when the foot is not in contact with the ground. It begins as soon as the foot leaves the floor and ends when the heel of the same foot touches the floor (Fig. 20-4). The swing phase makes up about 40 percent of the gait cycle (see Fig. 20-1).

When both feet are in contact with the ground at the same time, there is a period of **double support** (Fig. 20-5). This occurs between heel-off and toe-off of one limb and between heel strike and foot flat on the opposite (contralateral) side. In other words, it is that period when one limb is ending its stance phase and the other limb is beginning its stance phase. Therefore, there are two periods of double support: one when the right leg is ending its stance phase and the other when the left leg is ending its stance phase. Each period of double support takes up about 10 percent of the gait cycle at an average walking speed (see Fig. 20-1). If you increase your walking speed, you spend less time with both feet on the ground. Conversely, you spend more time in double support when you walk slowly.

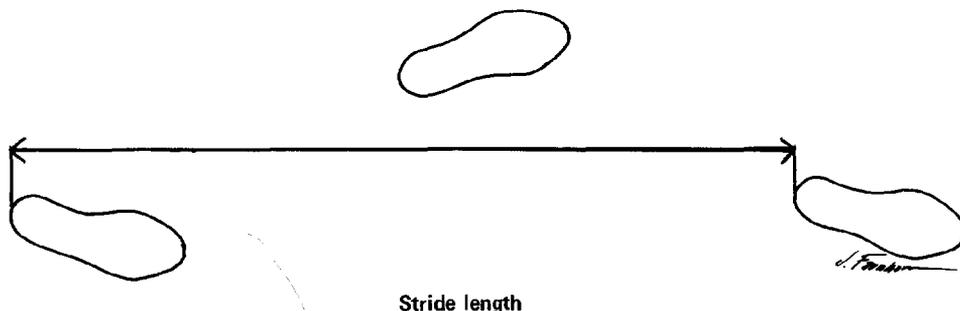


FIGURE 20-2. Stride length. (From Norkin, CC and Levangie, PK: *Joint Structure and Function: A Comprehensive Analysis*, ed 2. FA Davis, Philadelphia, 1992, p 457, with permission.)

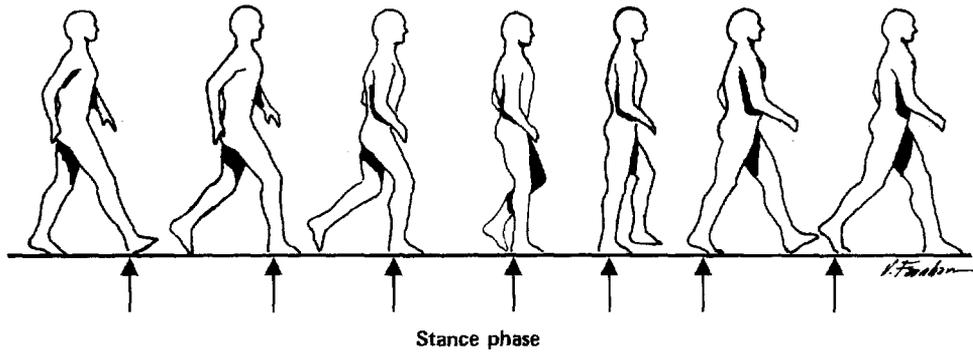


FIGURE 20-3. Stance phase. (From Norkin, CC and Levangie, PK: Joint Structure and Function: A Comprehensive Analysis, ed 2. FA Davis, Philadelphia, 1992, p 451, with permission.)

A period of **nonsupport**, that is, a time during which neither foot is in contact with the ground, does not occur during walking. However, nonsupport does occur during running. This may be the biggest difference between running and walking. Other activities, such as hopping, skipping, and jumping, have a period of nonsupport but lose the order of progression that walking and running have. In other words, these activities do not include all the parts of stance and swing phase as do walking and running.

The period of **single support** occurs when only one foot is in contact with the ground (see Fig. 20-5). Thus, two periods of single support occur: once when the right foot is on the ground and then again when the left foot bears weight. Each single support period takes up about 40 percent of the gait cycle.

As you can see in Figure 20-1, the right and left step times are equal. A **step** includes a period of double support and single support as well as a stance and swing phase. A **step length** is that distance between heel strike of one limb and heel strike of the other (Fig. 20-6). Even with an increased or decreased walking speed, the step percentage of each limb should remain equal. Walking speed, or **cadence**, the number of steps taken per minute, varies greatly. Slow walking may be as slow as 70 steps per minute. However, students on their way to an examination have been

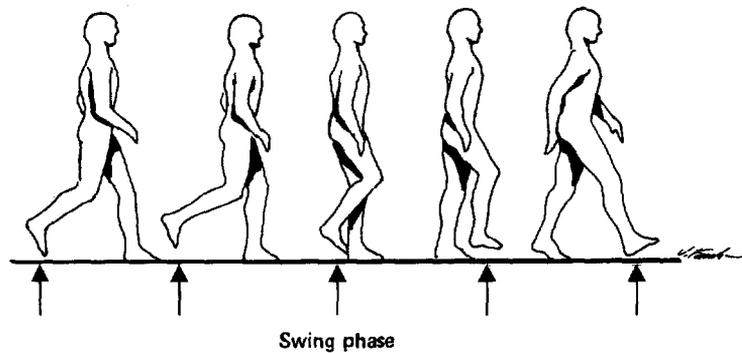


FIGURE 20-4. Swing phase. (From Norkin, CC and Levangie, PK: Joint Structure and Function: A Comprehensive Analysis, ed 2. FA Davis, Philadelphia, 1992, p 452, with permission.)

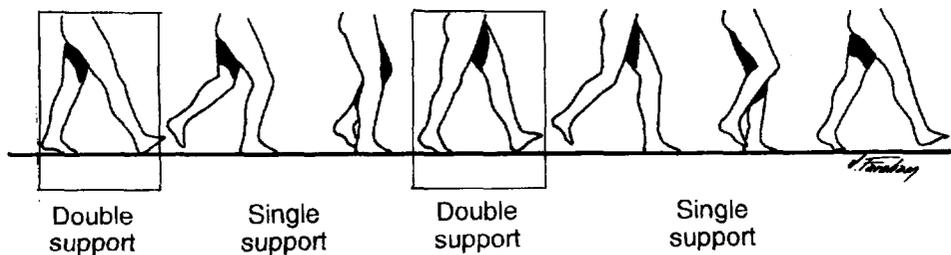


FIGURE 20-5. Periods of double support and single support. (From Norkin, CC and Levangie, PK: *Joint Structure and Function: A Comprehensive Analysis*, ed 2. FA Davis, Philadelphia, 1992, p 452, with permission.)

clocked at much slower speeds. Fast walking may be as fast as 130 steps per minute, although race walkers will walk much faster. Regardless of speed, the phase relationship is the same; that is, all parts occur in their proper place at the proper time.

Many sets of terms have been developed from the original, or traditional, terminology to describe the components of walking. In many cases, although the terminology may be accurate, it is often cumbersome. However, terminology developed by the Gait Laboratory at Rancho Los Amigos (RLA) Medical Center has been gaining in acceptance. Perhaps the biggest difference between the two sets of terminology is that the traditional terms refer to *points in time* whereas RLA terms refer to *periods of time*. Although it is best to be familiar with both sets of terms, traditional terminology will be used here. Table 20-1 provides the definitions of traditional terminology as well as the RLA terms. In comparison, one can see that they are similar with a few notable exceptions.

Analysis of Stance Phase

As defined earlier, *stance* is that period in which the foot is in contact with the floor. Traditionally, the stance phase has been broken down into five components consisting of (1) heel strike, (2) foot flat, (3) midstance, (4) heel-off, and (5) toe-off (see Fig. 20-3). Some sources break stance down into only four components, combining heel-off and toe-off into one, calling it "push-off." Because significantly different activities occur during these two periods, it is perhaps best to keep them separated.

Heel strike signals the beginning of stance phase the moment the heel comes

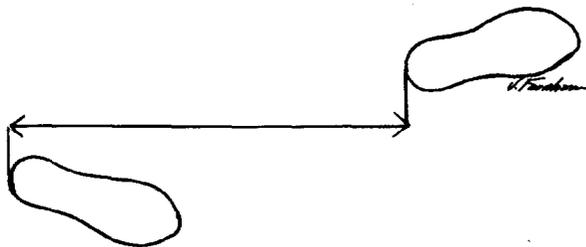


FIGURE 20-6. Step length. (From Norkin, CC and Levangie, PK: *Joint Structure and Function: A Comprehensive Analysis*, ed 2. FA Davis, Philadelphia, 1992, p 457, with permission.)

TABLE 20-1 | COMPARISON OF GAIT TERMINOLOGY

<i>Traditional</i>		<i>Rancho Los Amigos</i>	
Term	Definition	Term	Definition
<i>Stance Phase</i>			
Heel strike	Heel contact with ground	Initial contact	Same
Foot flat	Plantar surface of the foot contacts ground	Loading response	Period from just after initial contact until the opposite foot leaves the ground
Midstance	Point at which the body passes over the weight-bearing limb	Midstance	Period from when the opposite foot leaves to ground until body is directly over the weight-bearing limb
Heel-off	Heel leaves the ground, while ball of the foot and toes remain in contact with the ground	Terminal stance	From midstance to initial contact of the opposite foot
Toe-off	Toes leave the ground, ending stance phase	Preswing	From initial contact of the opposite limb to just before the toes leave ground
<i>Swing Phase</i>			
Acceleration	From when the toes leave the ground until the foot is directly under the body	Initial swing	From when the toes leave the ground until maximum knee flexion of the same limb
Midswing	When the non-weight-bearing limb is directly under the body	Midswing	Just after maximum knee flexion until the tibia is in a vertical position
Deceleration	When the limb is slowing down in preparation for heel strike	Terminal swing	From the vertical position of the tibia to just prior to initial contact

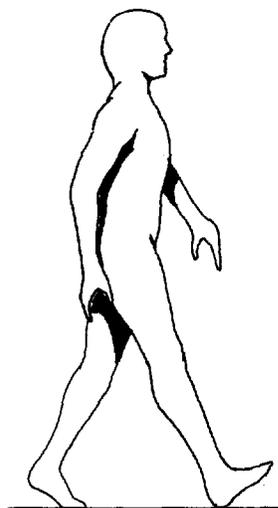


FIGURE 20-7. Heel strike. (From Norkin, CC and Levangie, PK: *Joint Structure and Function: A Comprehensive Analysis*, ed 2. FA Davis, Philadelphia, 1992, p 453, with permission.)

in contact with the ground (Fig. 20-7). At this point the ankle is in a neutral position between dorsiflexion and plantar flexion, and the knee begins to flex. This slight flexion provides some shock absorption as the foot hits the ground. The hip is in about 25 degrees of flexion. The trunk is erect and remains so through the entire gait cycle. The trunk is rotated to the opposite side, the opposite arm is forward, and the same-side arm is back in shoulder hyperextension. At this point, body weight begins to shift onto the stance leg.

The ankle dorsiflexors are active in putting the ankle in its neutral position. The quadriceps, which have been contracting concentrically, switch to contracting eccentrically to minimize the amount of knee flexion. The hip flexors have been active. However, the extensors are beginning to contract, keeping the hip from flexing more. The erector spinae are active in keeping the trunk from flexing. The force of the foot hitting the ground transmits up through the ankle, knee, and hip to the trunk. This would cause the pelvis to rotate anteriorly, flexing the trunk somewhat, if it were not for the erector spinae counteracting this force.

“Foot flat,” when the entire foot is in contact with the ground, occurs shortly after heel strike (Fig. 20-8). The ankle moves into about 15 degrees of plantar flexion with the dorsiflexors contracting eccentrically to keep the foot from “slapping” down on the floor. The knee moves into about 20 degrees of flexion. The hip is moving into extension, allowing the rest of the body to begin catching up with the leg. Weight shift onto the stance limb continues.

The point at which the body passes over the weight-bearing foot is called **mid-stance** (Fig. 20-9). In this phase, the ankle moves into slight dorsiflexion. However, the dorsiflexors become inactive. The plantar flexors begin to contract, controlling the rate at which the leg moves over the ankle. The knee and hip continue to extend, both arms are in shoulder extension essentially parallel with the body, and the trunk is in a neutral position of rotation. It is here that the body reaches its highest point in the gait cycle and is in a period of single support.

Following midstance is **heel-off**, in which the heel rises off the floor (Fig. 20-10). The ankle will dorsiflex slightly (approximately 15 degrees) and then begin to plantar flex. This is the beginning of the **push-off** phase, in which the ankle plan-

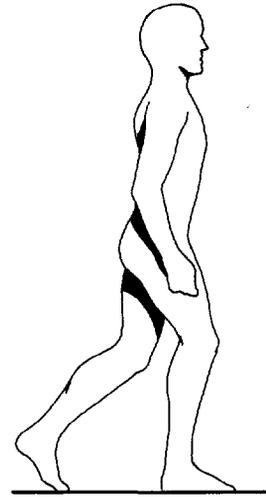


FIGURE 20-8. Foot flat. (From Norkin, CC and Levangie, PK: *Joint Structure and Function: A Comprehensive Analysis*, ed 2. FA Davis, Philadelphia, 1992, p 453, with permission.)

tar flexors are active in pushing the body forward. The knee is in near full extension, and the hip has moved into hyperextension. The trunk has begun to rotate to the same side, and the arm is swinging forward into shoulder flexion.

Toe-off is that period just before and including when the toes leave the ground, signaling the end of stance phase and the beginning of swing (Fig. 20-11). The ankle moves into about 10 degrees of plantar flexion, and the knee and hip are flexing.

Analysis of Swing Phase

The swing phase consists of three components: acceleration, midswing, and deceleration (see Fig. 20-4). These components are all non-weight-bearing activities. With



FIGURE 20-9. Midstance. (From Norkin, CC and Levangie, PK: *Joint Structure and Function: A Comprehensive Analysis*, ed 2. FA Davis, Philadelphia, 1992, p 453, with permission.)

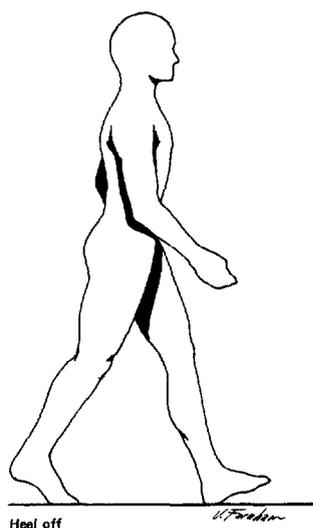


FIGURE 20-10. Heel off. (From Norkin, CC and Levangie, PK: Joint Structure and Function: A Comprehensive Analysis, ed 2. FA Davis, Philadelphia, 1992, p 454, with permission.)

acceleration, the limb is behind the body and moving to catch up (Fig. 20-12). The ankle is dorsiflexing, and the knee and hip continue to flex.

At **midswing**, the ankle dorsiflexors have brought the ankle to a neutral position. The knee is at its maximum flexion (approximately 65 degrees) as is the hip (at about 25 degrees of flexion). These motions act to shorten the limb, allowing the foot to clear the ground as it swings through (Fig. 20-13).

In **deceleration**, the ankle dorsiflexors are active to keep the ankle in a neutral position in preparation for heel strike (Fig. 20-14). The knee is extending, and the hamstring muscles are contracting eccentrically to slow down the leg, keeping it from snapping into extension.

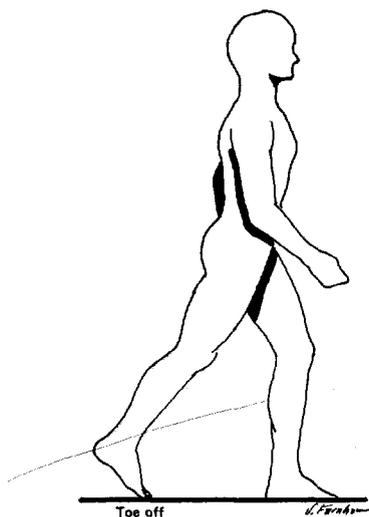


FIGURE 20-11. Toe off. (From Norkin, CC and Levangie, PK: Joint Structure and Function: A Comprehensive Analysis, ed 2. FA Davis, Philadelphia, 1992, p 454, with permission.)

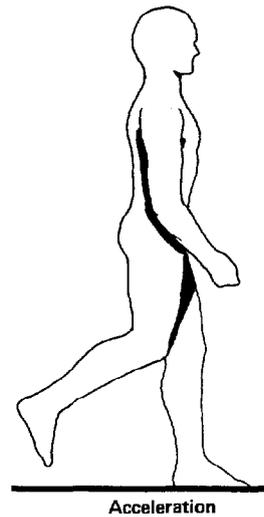


FIGURE 20-12. Acceleration. (From Norkin, CC and Levangie, PK: Joint Structure and Function: A Comprehensive Analysis, ed 2. FA Davis, Philadelphia, 1992, p 455, with permission.)

Additional Determinants of Gait

To this point, the description of gait has centered mostly on the lower limbs. However, other events are occurring in the rest of the body that must also be considered.

If you were to hold a piece of chalk against the blackboard and walk its length, you would see that the line drawn bobs up and down in wavelike fashion. This is described as the **vertical displacement** of the center of gravity (Fig. 20-15). The normal amount of this displacement is approximately 2 inches, being highest at midstance and lowest at heel strike. There is also an equal amount of **horizontal displacement** of the center of gravity as the body weight shifts from side to side. This displacement is greatest during the single support phase at midstance.

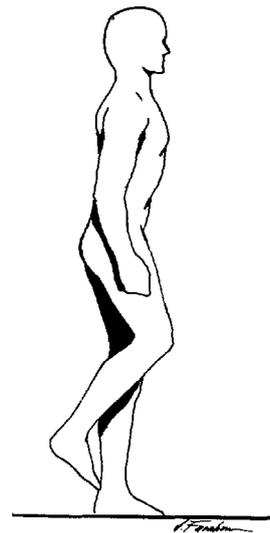


FIGURE 20-13. Midswing. (From Norkin, CC and Levangie, PK: Joint Structure and Function: A Comprehensive Analysis, ed 2. FA Davis, Philadelphia, 1992, p 455, with permission.)

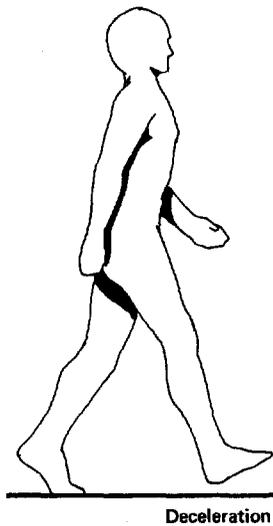


FIGURE 20-14. Deceleration. (From Norkin, CC and Levangie, PK: *Joint Structure and Function: A Comprehensive Analysis*, ed 2. FA Davis, Philadelphia, 1992, p 456, with permission.)

When you walk, you do not place your feet one step in front of the other but slightly apart. If lines were drawn through the successive midpoints of heel contact on each foot, this distance would range from 2 to 4 inches. This is described as the **width of walking base** (Fig. 20-16).

If you were to walk across the room with your hands on your hips, you would notice that they move up and down as your pelvis on each side drops down slightly. This **lateral pelvic tilt** occurs when weight is taken off the limb at toe-off (Fig. 20-17). This dip would be greater if it were not for the hip abductors on the *opposite* side and the erector spinae on the same side working together keeping the pelvis essentially level. When the pelvis drops on the right side (non-weight-bearing side), the left hip (weight-bearing side) is forced into adduction. To keep the pelvis level, actually dipping slightly, the left hip abductors contract to prevent hip adduction. At the same time the right erector spine muscle, which has an attachment on the pelvis, contracts and "pulls up" on the side of the pelvis wanting to drop (Fig. 20-18).

In addition, step length should be equal in both distance and time. The arms should swing with the opposite leg. The trunk rotates forward as the limb progresses through the swing phase. Arms swinging in opposition to trunk rotation control the amount of trunk rotation by providing counterrotation. The head should be erect, shoulders level, and trunk in extension.

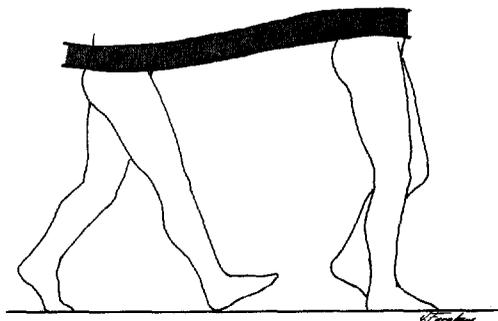
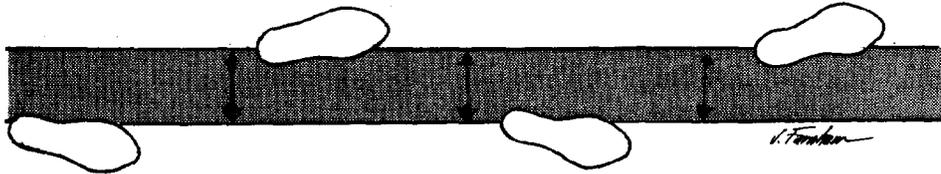


FIGURE 20-15. Vertical displacement of the center of gravity. (From Norkin, CC and Levangie, PK: *Joint Structure and Function: A Comprehensive Analysis*, ed 2. FA Davis, Philadelphia, 1992, p 461, with permission.)



Width of base of support

FIGURE 20-16. Width of walking base. (From Norkin, CC and Levangie, PK: Joint Structure and Function: A Comprehensive Analysis, ed 2. FA Davis, Philadelphia, 1992, p 458, with permission.)

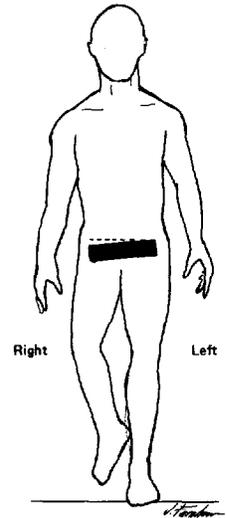


FIGURE 20-17. Lateral pelvic tilt. (From Norkin, CC and Levangie, PK: Joint Structure and Function: A Comprehensive Analysis, ed 2. FA Davis, Philadelphia, 1992, p 462, with permission.)

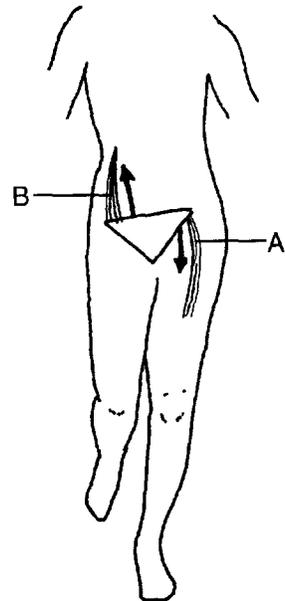


FIGURE 20-18. Muscles working to minimize lateral pelvic tilt. (A) Hip abductors. (B) Erector spinae muscle.

When analyzing someone's gait, it is best to view the person from both the side and the front (or back). Step length, arm swing, position of head and trunk, and the activities of the lower limb are usually best viewed from the side. Width of walking base, dip of the pelvis, and position of the shoulders and head should be viewed from the front or back.

Abnormal Gait

Although it is not within the scope of this text to cover gait abnormalities, some of the more common or significant problems are included for an introductory understanding. Walking abnormally can range from having an early heel rise as a result of tight calf muscles to the waddling gait for a person with muscular dystrophy. There are many methods of classifying abnormal gait. The following is a listing of abnormal gaits based on general cause or basis for the abnormality:

- Muscular weakness/paralysis
- Joint muscle range of motion (ROM) limitation
- Neurologic involvement
- Pain
- Leg length discrepancy

MUSCULAR WEAKNESS/PARALYSIS

Generally speaking, with muscle weakness, the body tends to compensate by shifting the center of gravity over, or toward, the part that is involved. Obviously, the portion of the gait cycle affected will be that portion in which the muscles or joint have a major role. In the case of the **gluteus maximus gait**, the trunk quickly shifts posteriorly at heel strike. With the foot in contact with the floor, the hip is maintained in extension during stance phase. This shifting is sometimes referred to as a "rocking horse" gait because of the extreme backward-forward movement of the trunk.

With a **gluteus medius gait**, the individual shifts the trunk to the affected side during stance phase. When the left gluteus medius, or hip abductor, is weak, the right side of the pelvis will drop when the right leg leaves the ground and begins swing phase. This gait is also referred to as a "Trendelenburg" gait.

When there is weakness in the **quadriceps** muscle group, several different compensatory mechanisms may be used. If only the quadriceps group is involved, the individual may be able to use the hip extensors and triceps surae to pull the knee into extension at heel strike. This reversal of muscle action has been described in Chapter 17. However, if these muscles are also involved, the person may physically push the knee into extension during stance phase.

If the **hamstrings** are weak, two things may happen. During stance phase, the knee will go into excessive hyperextension, sometimes referred to as "genu recurvatum" gait. During the deceleration part of swing phase, without the hamstrings to slow down the swing forward of the lower leg, the knee will snap into extension.

Depending on how involved the **ankle dorsiflexors** are, the individual may compensate in several ways. If they are weak, they may not be able to support the weight of the body at heel strike as they eccentrically contract. The result is "foot slap." With the dorsiflexors not being able to slow the descent of the foot, the foot slaps into plantar flexion. Depending on how weak these muscles are, they may or

may not be able to dorsiflex the ankle during swing phase. If not, or if the muscles are paralyzed, a "foot drop" or "steppage" gait will result. This is seen first during the swing phase. The knee will have to be lifted higher for the drop foot (plantar flexed) to clear the floor. Secondly, instead of heel strike, there is *toe strike*. The ankle dorsiflexors are not able to bring the ankle into dorsiflexion so that the heel can strike first. Instead, the ankle remains in plantar flexion and the toes strike first.

When the **triceps surae group** (the gastrocnemius and soleus) are weak, there is no heel rise at push off, resulting in a shortened step length on the unaffected side. This is sometimes referred to as a "sore foot limp." Although this gait is noticeable on level ground, it becomes most pronounced when walking up an incline.

A **waddling gait** is commonly seen with muscular and other types of dystrophies. The person stands with the shoulders behind the hips, much like a person with paraplegia would balance resting on the iliofemoral ligament of the hips. Little or no reciprocal pelvis and trunk rotation occurs. Therefore, to swing the leg forward, that entire side of the body must swing forward, hence the waddling nature of the gait. Lumbar lordosis and a steppage gait also are also often present.

JOINT/MUSCLE ROM LIMITATION

In this grouping, the joint ankyloses is unable to go through its normal ROM because either there is bony fusion or soft tissue limitation. This limitation can be the result of contractures of muscle, capsule, or skin.

When a person has a **hip flexion contracture**, the hip is unable to go into hip extension and hyperextension during the midstance and push-off phases. To compensate, the person will increase the anterior pelvic tilt and lumbar lordosis. The involved limb may also have simultaneous knee flexion. If the hip is **fused**, the lumbar spine and pelvis primarily compensate for the hip motion. Decreased lordosis and posterior pelvic tilt will allow the limb to swing forward, while increased lordosis and anterior pelvic tilt will swing the limb posteriorly. This is sometimes referred to as a "bell-clapper gait."

A **knee flexion contracture** will result in excessive dorsiflexion during midstance and an early heel rise during push-off. There is also a shortened step length of the unaffected side. If a **knee fusion** is present, the lower limb will be at a fixed length. That length will depend on the position of the joint. If the knee is in extension, the limb will be unable to shorten during swing phase. Therefore, the limb must swing the leg out to the side. Called a "circumducted gait," the leg begins near the midline at push-off, swings out to the side during swing phase, then returns to the midline for heel strike. It is called an "abducted gait" if the limb remains in an abducted position throughout the gait cycle.

Depending on the severity of a **triceps surae contracture**, several things may result. An early heel rise occurs during push-off, the knee will be lifted higher during swing phase, and the toes will land first during heel strike. The latter is called a "steppage gait."

If an individual has an **ankle fusion**, commonly called a triple arthrodesis because of fusion between the subtalar and transverse tarsal joints, ankle plantar flexion and dorsiflexion will remain. However, these will be limited. Usually, there is a shortened stride length. The person will have more difficulty walking on uneven ground because the ability to pronate and supinate the foot has been lost.

NEUROLOGIC INVOLVEMENT

As would be expected, the amount of gait disturbance will depend on the amount and severity of neurologic involvement. A **hemiplegic gait** will vary somewhat de-

pending on the presence of spasticity or flaccidity. The person usually shifts the body primarily to the uninvolved side, circumducts the affected limb during swing phase, and lands flat-footed or toe-first at heel strike. The involved upper extremity may be in a flexed pattern and usually without reciprocal arm swing. Step length tends to be lengthened on the involved side and shortened on the uninvolved side.

Ataxic gait from cerebellar involvement is evidenced by a wide base of support (abducted gait), and jerky, unsteady movements. The person usually has difficulty walking in a straight line, and tends to stagger. Reciprocal arm motion also appears to be jerky, and uneven.

A **parkinsonian gait** demonstrates diminished movement. The posture of the lower extremities and trunk tends to be flexed, and the reciprocal arm swing and stride length are greatly diminished. The person walks with a shuffling gait and has difficulty initiating movements. Because of the flexed posture, the center of gravity is also forward. In advanced cases, this forward center of gravity results in a "festinating gait." Because the person's balance is too far forward, a series of short, rapid steps are used to regain balance.

Spasticity in the hip adductors results in a **scissors gait**. This gait is most evident during the swing phase in which the unsupported limb swings against or across the stance leg.

A **crouch gait** is often seen with bilateral involvement of the lower extremities. Excessive lumbar lordosis and anterior pelvic tilt, flexion of the hips and knees, and plantar flexion of the ankles occurs. To compensate, the reciprocal arm swing is exaggerated.

PAIN

When a person has pain in any of the joints of the lower extremity, the tendency is to shorten the stance phase. In other words, if it hurts to stand on it, do not stand on it. A shortened, often abducted, stance phase on the involved side results in a rapid and shortened step length of the uninvolved side. Compensation in the reciprocal arm swing also is evident. Reciprocal arm swinging is shortened as the step length is shortened, exaggerated, and often abducted. This gait is often referred to as **antalgic gait**.

LEG LENGTH DISCREPANCY

We all have legs of unequal length, usually a discrepancy of approximately 1/4 inch between the right and left legs. When the discrepancy is minimal, compensation occurs by dropping the pelvis on the affected side. Although this may not look abnormal, it does place added stress on the low back. Leg length discrepancies of up to 3 inches can be accommodated in this manner.

When the discrepancy is moderate, approximately between 3 and 5 inches, dropping the pelvis on the affected side will no longer be effective. A longer leg is needed, so the person usually walks on the ball of the foot on the involved (shorter) side. This is called an **equinus gait**.

A severe leg length discrepancy is usually any discrepancy over 5 inches. The person may compensate in a variety of ways. Dropping the pelvis and walking in an equinus gait plus flexing the knee on the uninvolved side is often used. To gain an appreciation for how this may feel or look, walk down the street with one leg in the street and the other on the sidewalk.