GAIT

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INTRODUCTION

- Human locomotion, or gait, may be described as a translatory progression of the body as a whole, produced by coordinated, rotatory movements of body segments.
- The alternating movements of the lower extremities essentially support and carry along the head, arms, and trunk.
- The head, arms, and trunk constitute about 75% of total body weight, with the head and arms contributing about 25% of total body weight and the trunk contributing the remaining 50%.

MAJOR TASKS OF GAIT

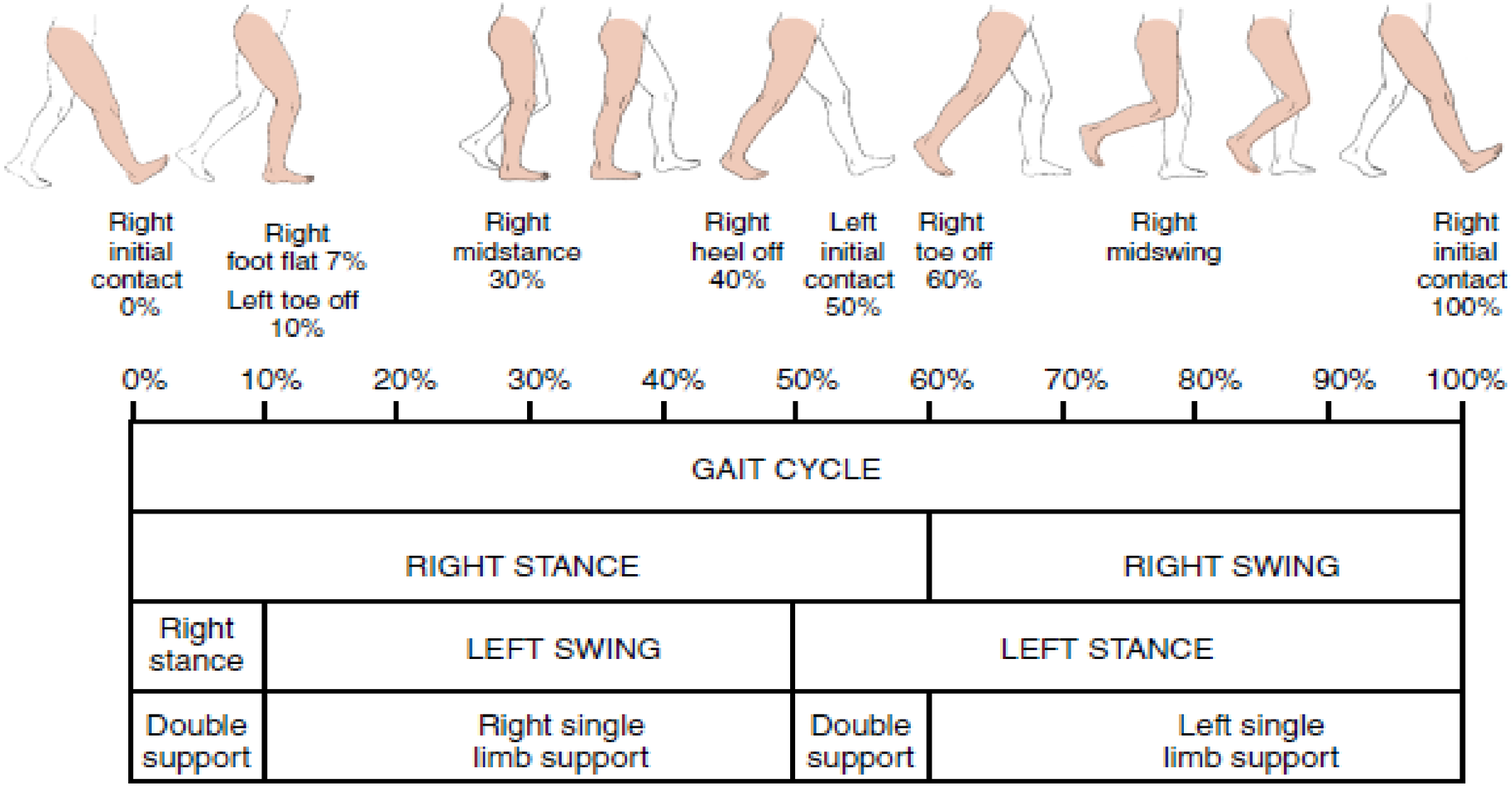
1. Maintenance of support of the head, arms, and trunk, that is, preventing collapse of the lower limb.
2. Maintenance of upright posture and balance of the body.
3. Control of the foot trajectory to achieve safe ground clearance and a gentle heel or toe landing
4. Generation of mechanical energy to maintain the present forward velocity or to increase the forward velocity.
5. Absorption of mechanical energy for shock absorption and stability or to decrease the forward velocity of the body.

PHASES OF THE GAIT CYCLE

- Gait has been divided into a number of segments that make it possible to describe, understand, and analyse the events that are occurring.
- A **gait cycle** spans two successive events of the same limb, usually initial contact of the lower extremity with the supporting surface.
- During one gait cycle, each extremity passes through two major phases:

1. A Stance Phase **2. A Swing Phase**

- A **stance phase,** when some part of the foot is in contact with the floor, which makes up about 60% of the gait cycle.
- A **swing phase,** when the foot is not in contact with the floor, which makes up the remaining 40%.
- There are two periods of **double support** occurring between the time one limb makes initial contact and the other one leaves the floor at toe-off. At a normal walking speed, each period of double support occupies about 11% of the gait cycle.


Right initial contact 0%
Right foot flat 7%
Left toe off 10%
Right midstance 30%
Right heel off 40%
Left initial contact 50%
Right toe off 60%
Right midswing
Right initial contact 100%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
GAIT CYCLE
RIGHT STANCE
RIGHT SWING
Right stance
LEFT SWING
LEFT STANCE
Double support
Right single limb support
Double support
Left single limb support

- Stance phase is divided into sub phases by a number of events that mark the start and end of the sub phases.

EVENTS IN STANCE PHASE

1. Heel Strike or Initial Contact or heel contact
2. Foot flat
3. Mid-stance
4. Heel off
5. Toe off

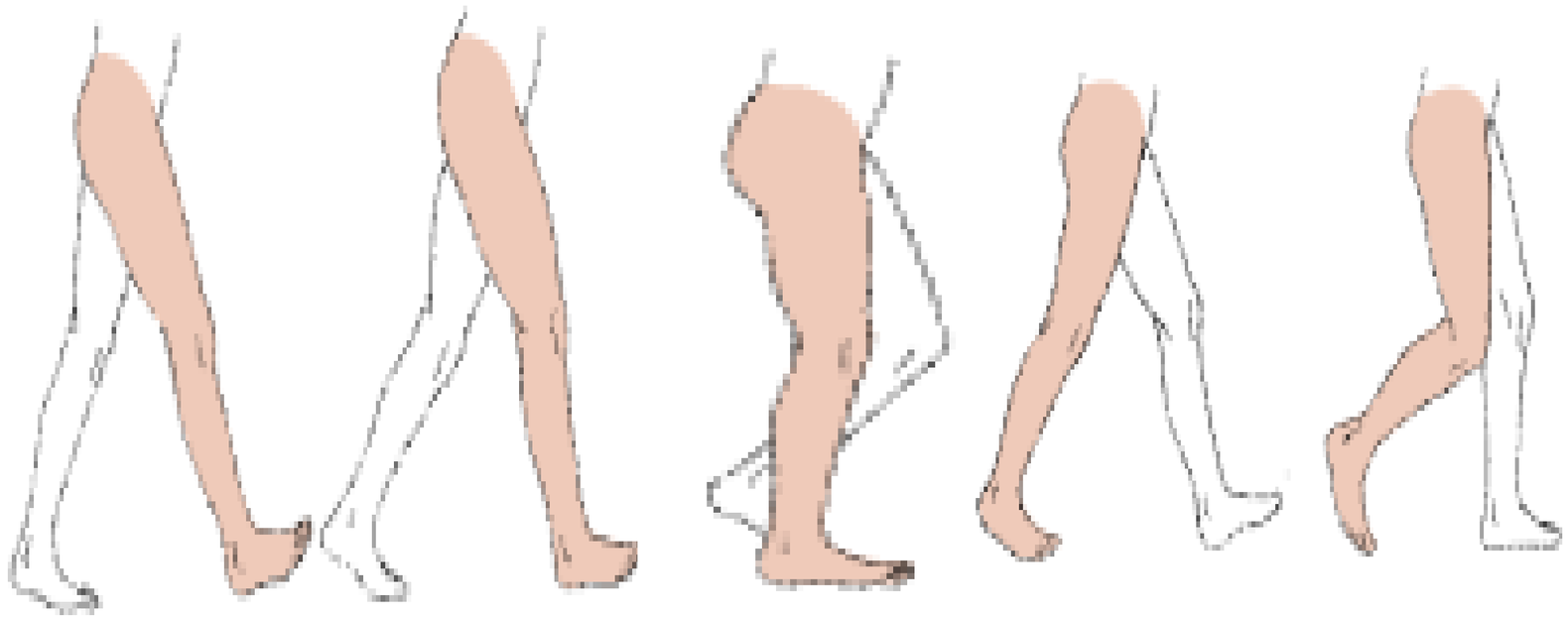
1. Initial contact refers to the instant the foot of the leading extremity strikes the ground. In normal gait, the heel is the point of contact, and the event referred to as heel contact or heel strike. In abnormal gait, it is possible for the whole foot or the toes, rather than the heel, to make initial contact with the ground.

2. Foot flat in normal gait occurs after initial contact at approximately 7% of the gait cycle. It is the first instant during stance when the foot is flat on the ground.

3. Mid-stance is the point at which the body weight is directly over the supporting lower extremity, usually about 30% of the gait cycle.

4. Heel-off is the point at which the heel of the reference extremity leaves the ground, usually about 40% of the gait cycle.

5. Toe-off is the instant at which the toe of the foot leaves the ground, usually about 60% of the gait cycle.

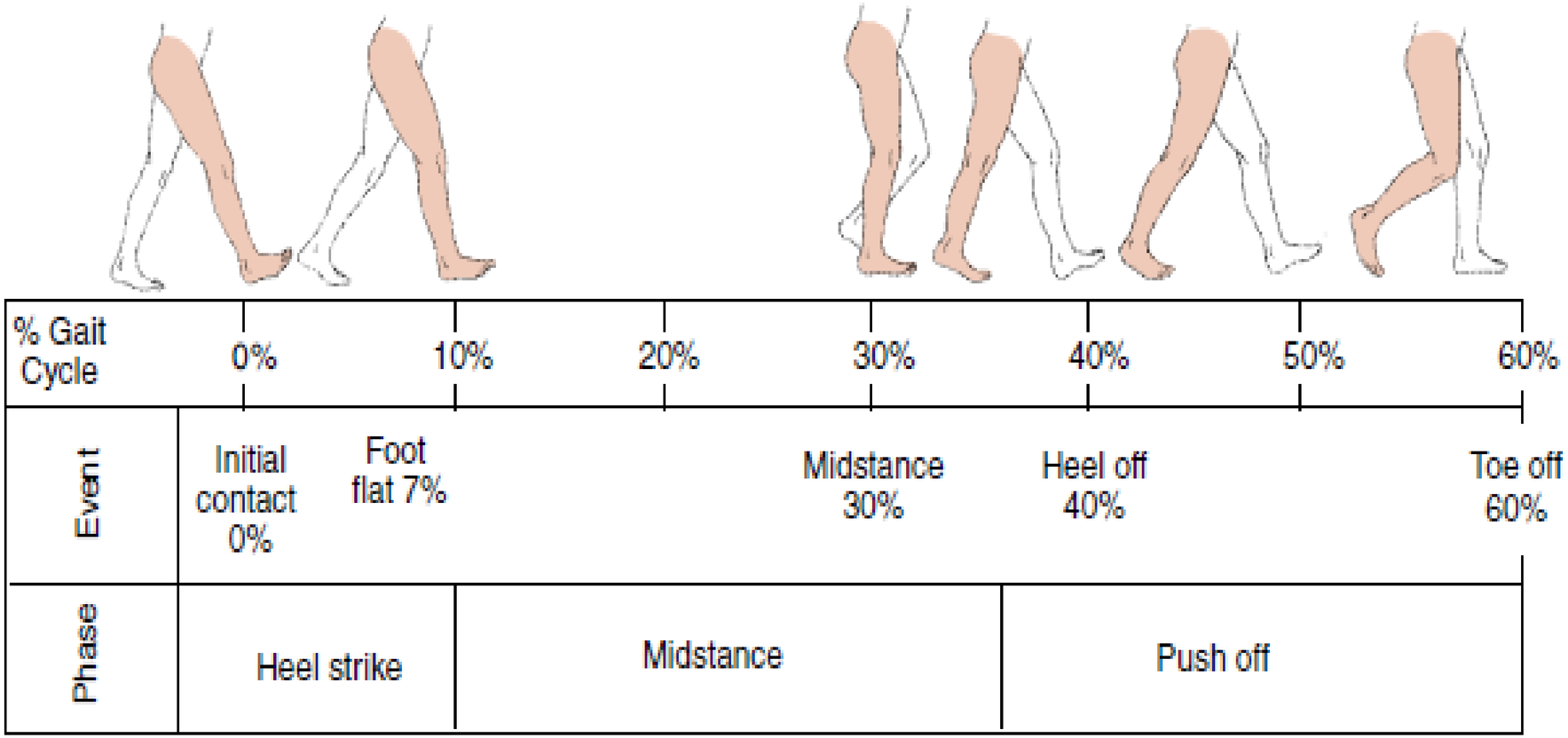


SUB PHASES OF STANCE PHASE

1. Heel strike phase begins with initial contact and ends with foot flat and occupies only a small percentage of the gait Cycle

2. Mid-stance phase begins with foot flat at 7% of the gait cycle and ends with heel-off at about 40% of the gait cycle.

3. Push-off phase begins with heel-off at about 40% of the gait cycle and ends with toe-off at about 60% of the gait cycle

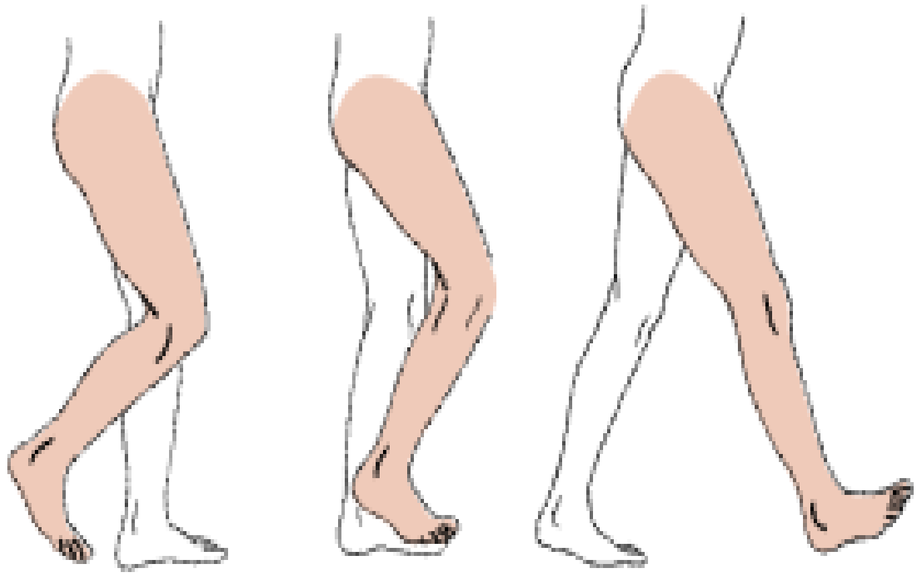

% Gait Cycle
0%
10%
20%
30%
40%
50%
60%
Event
Initial contact 0%
Foot flat 7%
Midstance 30%
Heel off 40%
Toe off 60%
Phase
Heel strike
Midstance
Push off

SWING PHASE

1. Early swing phase begins once the toe leaves the ground and continues until mid-swing, or the point at which the swinging extremity is directly under the body. This phase is also referred to as *initial swing*, or the *acceleration phase*.

2. Mid-swing occurs approximately when the extremity passes directly beneath the body, or from the end of acceleration to the beginning of deceleration.

3. Late swing occurs after mid-swing when the limb is decelerating in preparation for heel strike. It is also known as terminal swing, or the deceleration phase.



Early swing 60-75%	Midswing 75-85%	Late swing 85-100%

GAIT TERMINOLOGY

TIME AND DISTANCE TERMS:

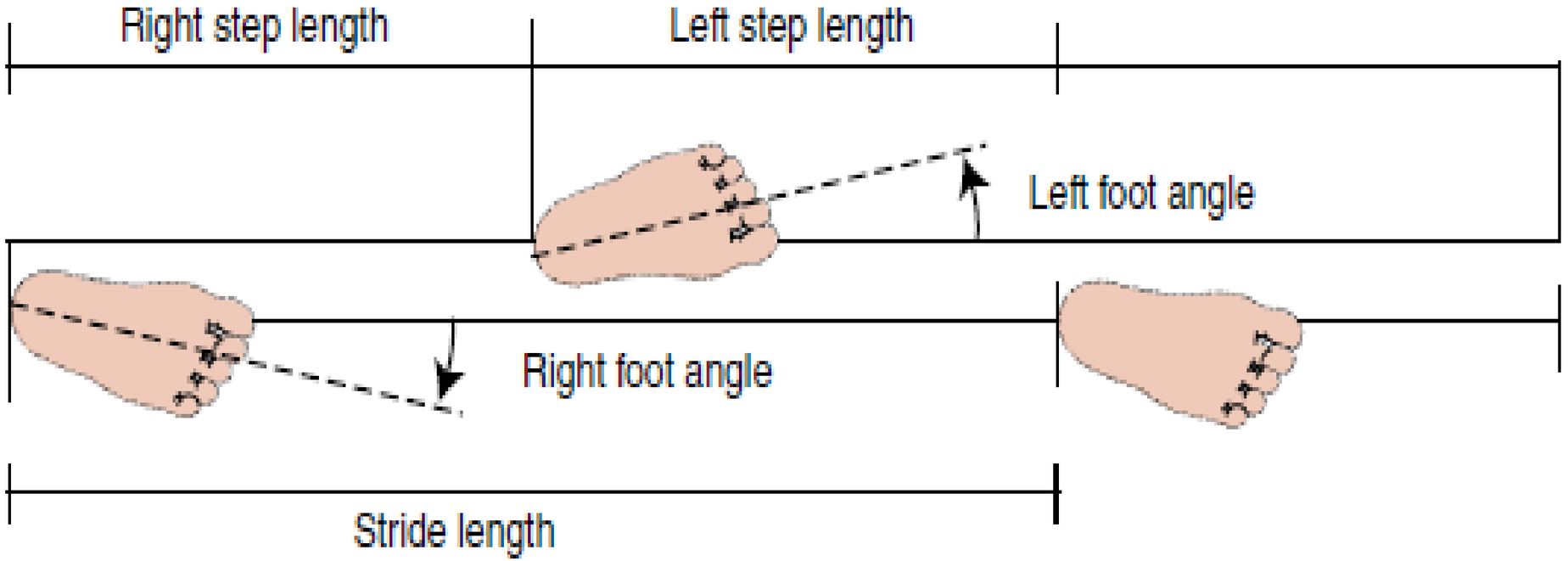
- The **Temporal variables** include stance time, single-limb and double-support time, swing time, stride and step time, cadence, and speed.
- The **distance variables** include stride length, step length and width, and degree of toe-out.

TEMPORAL VARIABLES

- **Stance time** is the amount of time that elapses during the stance phase of one extremity in a gait cycle.
- **Single-support time** is the amount of time that elapses during the period when only one extremity is on the supporting surface in a gait cycle.
- **Double-support time** is the amount of time spent with both feet on the ground during one gait cycle.

DISTANCE VARIABLES

- **Stride length** is the linear distance between two successive events that are accomplished by the *same* lower extremity during gait.
- In general, stride length is determined by measuring the linear distance from the point of one heel strike of one lower extremity to the point of the next heel strike of the same extremity.
- The length of one stride includes all of the events of one gait cycle.


Right step length
Left step length
Left foot angle
Right foot angle
Stride length

- Stride length also may be measured by using other events of the same extremity, such as toe-off, but in normal gait, two successive heel strikes are usually used.
- A stride includes two steps, a right step and a left step. However, stride length is not always twice the length of a single step, because right and left steps may be unequal.
- **Stride duration** refers to the amount of time it takes to accomplish one stride.

- **Step length** is the linear distance between two successive points of contact of *opposite* extremities. It is usually measured from the heel strike of one extremity to the heel strike of the opposite extremity.
- **Step duration** refers to the amount of time spent during a single step. Measurement usually is expressed as seconds per step. When there is weakness or pain in an extremity, step duration may be decreased on the affected side and increased on the unaffected (stronger) or less painful side.

- **Cadence** is the *number* of steps taken by a person per unit of time. Cadence may be measured as the number of steps per second or per minute.
- A shorter step length will result in an increased cadence at any given velocity.
- When a person walks with a cadence between 80 and 120 steps per minute, cadence and stride length had a linear relationship.

- As a person walks with increased cadence, the duration of the double-support period decreases.
- When the cadence of walking approaches 180 steps per minute, the period of double support disappears, and running commences.
- A step frequency or cadence of about 110 steps per minute can be considered as “typical” for adult men; a typical cadence for women is about 116 steps per minute.

- **Walking velocity** is the rate of linear forward motion of the body, which can be measured in meters or centimetre per second, meters per minute, or miles per hour.

  Walking velocity (meters/second) = distance walked (meters)/time (seconds)

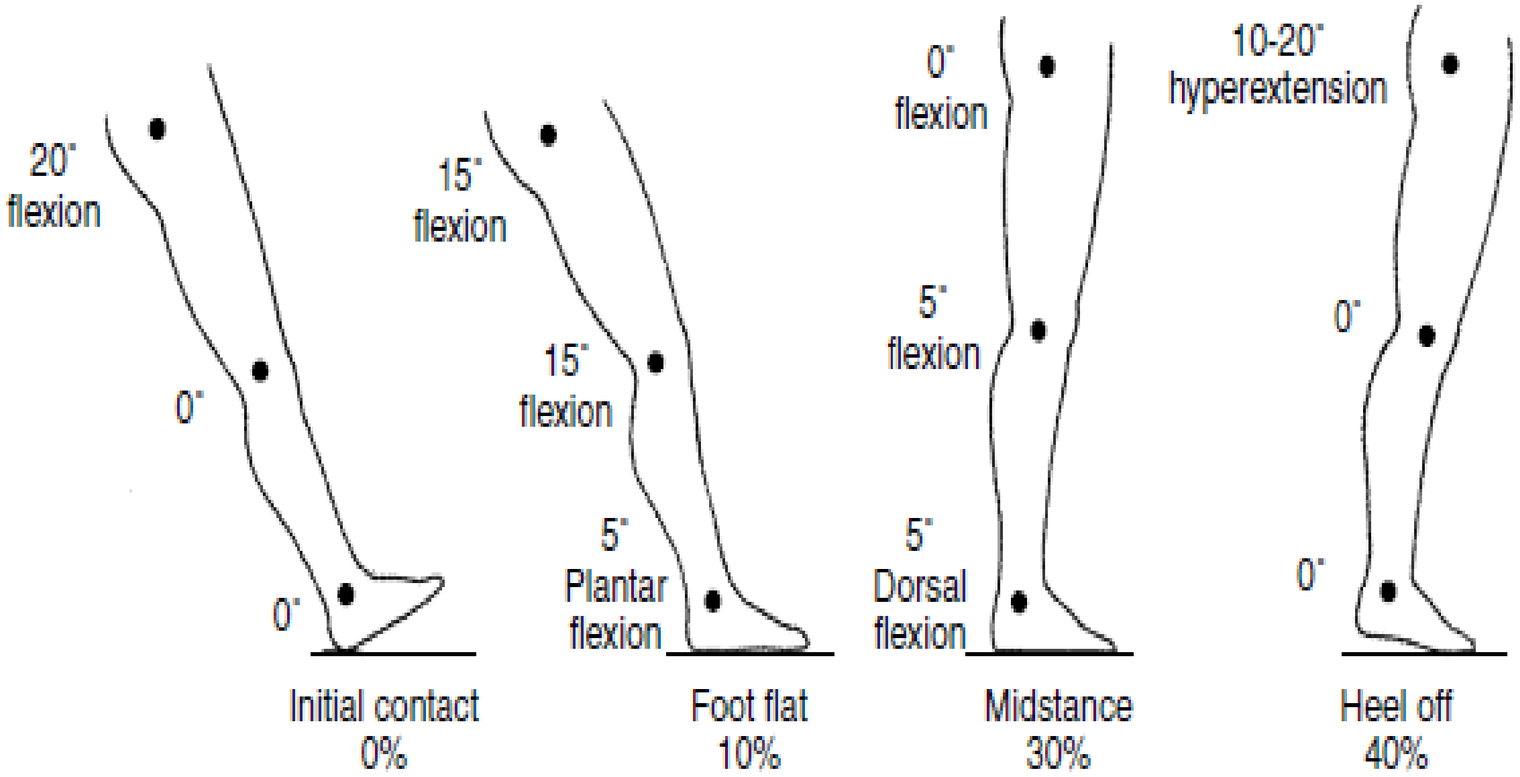
- **Step width,** or width of the walking base, may be found by measuring the linear distance between the midpoint of the heel of one foot and the same point on the other foot

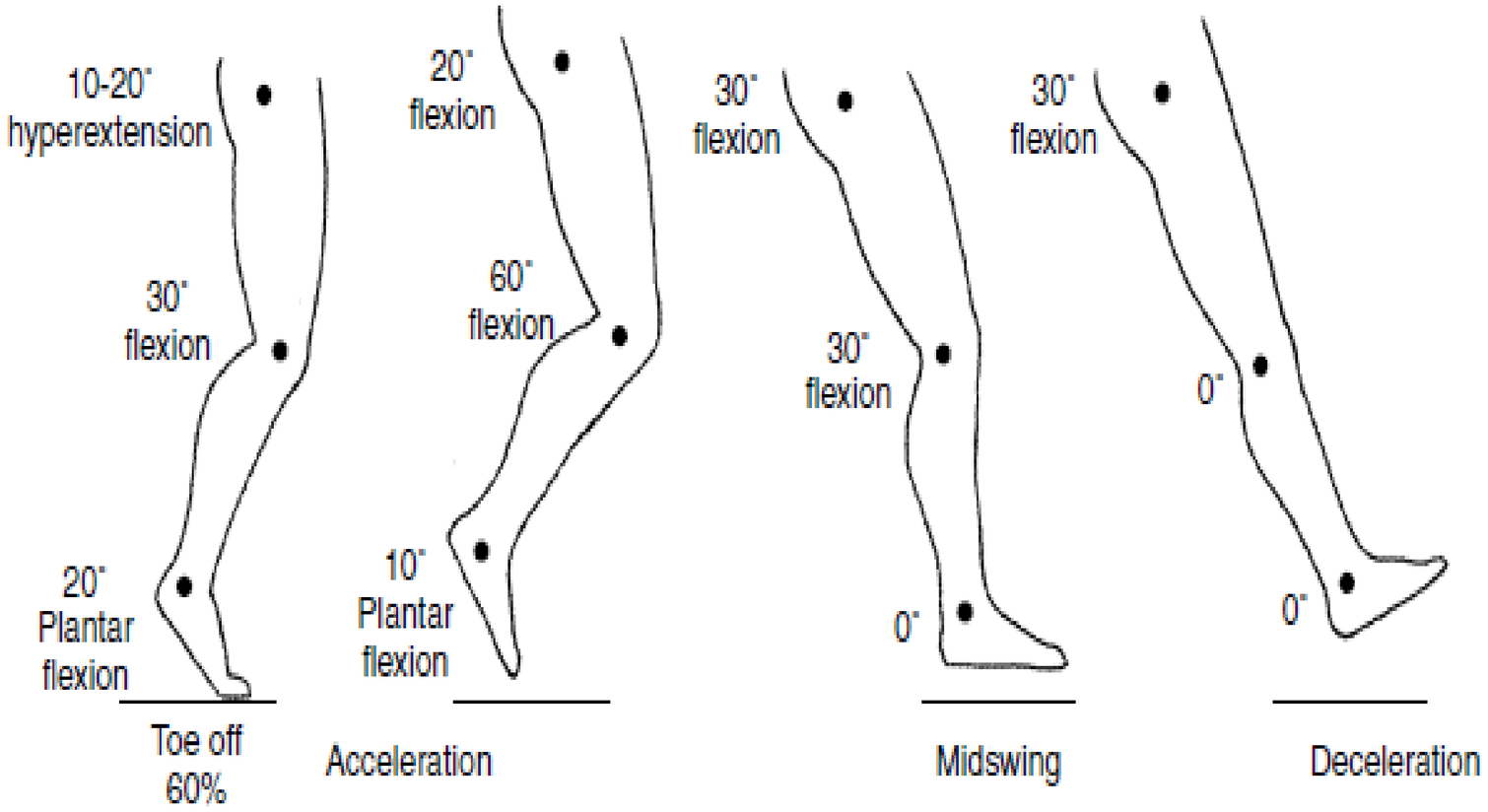
- **Degree of toe-out** represents the angle of foot placement and may be found by measuring the angle formed by each foot's line of progression and a line intersecting the center of the heel and the second toe.
- The angle for men normally is about 7° from the line of progression of each foot at free speed walking

CHARACTERISTICS OF NORMAL GAIT

SAGITTAL PLANE JOINT ANGLES

- The approximate range of motion (ROM) needed in normal gait and the time of occurrence of the maximum flexion and extension positions for each major joint may be determined by examining the joint angle profiles.
- In the anatomical position, the hip, knee, and ankle are at approximately 0°. Flexion for the hip and knee and dorsiflexion for the ankle are given positive values, and extension and plantarflexion are given negative values.


20° flexion
0°
0°
Initial contact 0%
15° flexion
15° flexion
5° Plantar flexion
Foot flat 10%
0° flexion
5° flexion
5° Dorsal flexion
Midstance 30%
10-20° hyperextension
0°
0°
Heel off 40%


10-20˚
hyperextension
30˚
flexion
20˚
Plantar
flexion
Toe off
60%
20˚
flexion
60˚
flexion
10˚
Plantar
flexion
Acceleration
30˚
flexion
30˚
flexion
0˚
Midswing
30˚
flexion
0˚
0˚
Deceleration

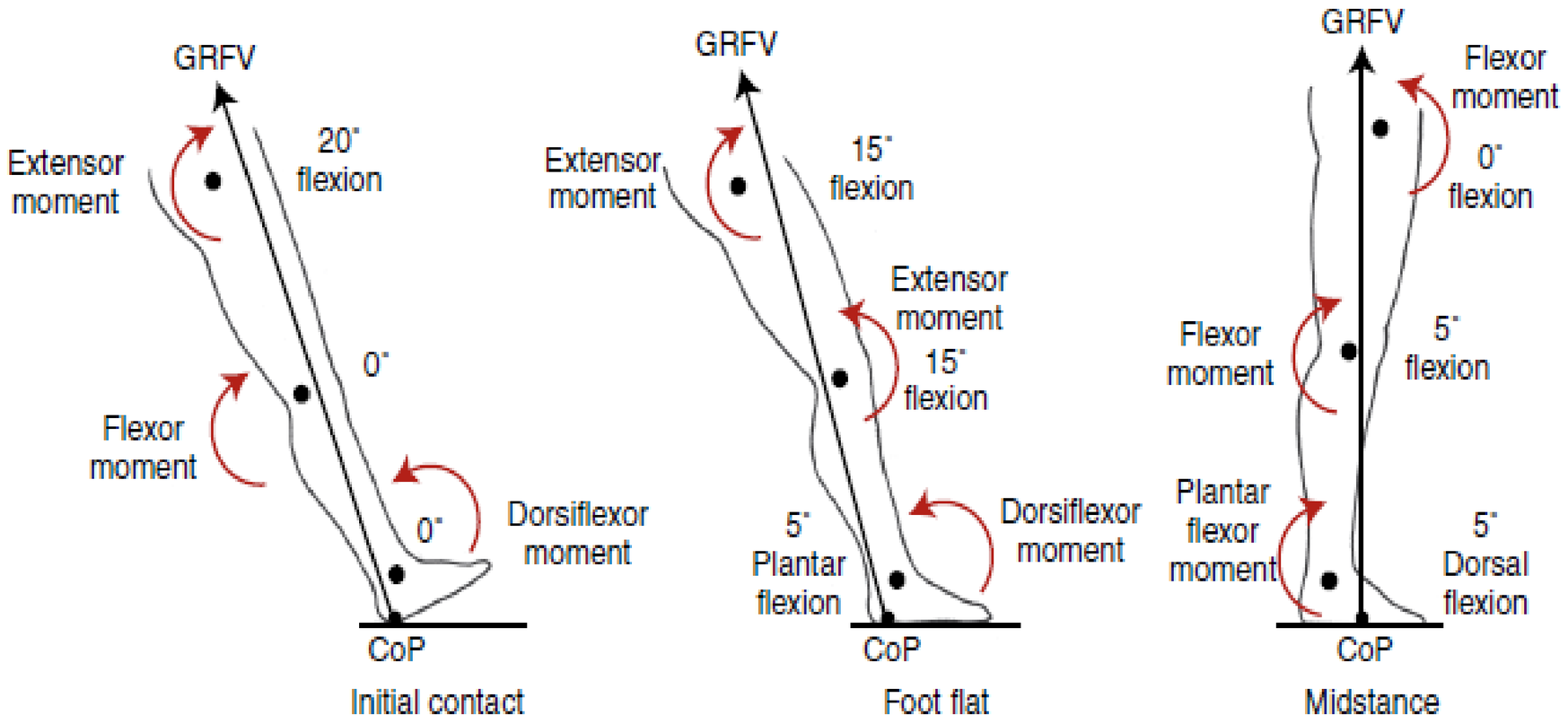
- The hip achieves maximum flexion (~+20°) around initial contact at 0% of the gait cycle and reaches its most extended position (~–20°) at about 50% of the gait cycle, between heel-off and toe-off.
- The knee is straight (0°) at initial contact and nearly straight again just before heel-off at 40% of the gait cycle.
- During the swing phase, the knee reaches its maximum flexion of ~+60° at ~70% of the gait cycle.

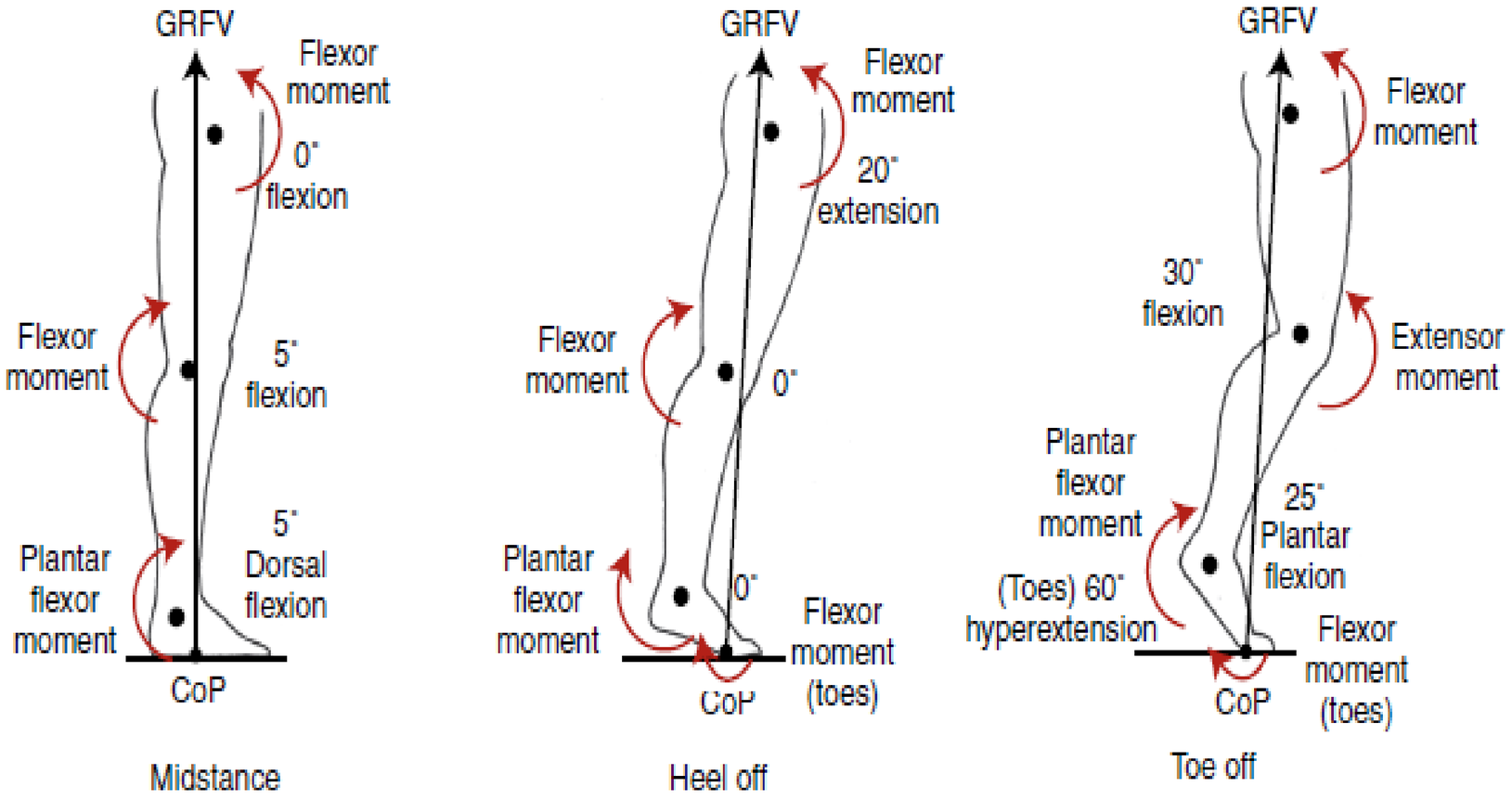
- The ankle reaches maximum dorsiflexion of ~+7° at approximately heel-off at about 40% of the gait cycle and reaches maximum plantarflexion (–25°) at toe-off (60%).

FRONTAL PLANE JOINT ANGLES

- During the first 20% of stance, the pelvis or the contralateral side drops about 5°, which results in adduction of the hip. The hip abducts smoothly to about 5° of abduction, peaking about toe-off, then returns to neutral at initial contact.
- The knee remains more or less neutral, except for a brief abduction peaking at about 7° in mid-swing, and then returns to neutral.

SAGITTAL PLANE MOMENTS




GRFV
Flexor moment
0° flexion
Flexor moment
5° flexion
5° Dorsal flexion
Plantar flexor moment
CoP
Midstance
GRFV
Flexor moment
20° extension
Flexor moment
0°
Plantar flexor moment
0°
Flexor moment (toes)
CoP
Heel off
GRFV
Flexor moment
30° flexion
Extensor moment
Plantar flexor moment
25° Plantar flexion
(Toes) 60° hyperextension
Flexor moment (toes)
CoP
Toe off

MUSCLE ACTIVITY

- During a gait cycle, virtually all muscles of the lower extremities exhibit one or two short bursts of electrical activity, lasting from generally 100 to 400 m sec (about 10% to 40% of the gait cycle).
- Activity of the lower extremity and trunk musculature has been studied extensively using EMG.
- In its simplest interpretation, muscular activity can be determined on a temporal basis; the muscle is simply considered “on” or “off.”

TRUNK

ERECTOR SPINAE:

- The erector spinae, at the level of the lumbar region, show two well-defined periods of activity. The first period is from slightly before heel contact to about 20% of the gait cycle. The second period is from 45% to 70% of the gait cycle, which corresponds to opposite heel contact.
- These two bursts of activity, from both the right and the left erector spinae, control the forward angular momentum of the trunk relative to the hips shortly after heel contact for each step.

RECTUS ABDOMINIS:

- This muscle has very low and variable activity throughout the gait cycle. Increased activity occurs at between 20% and 40% and again at between 70% and 90% of the gait cycle.
- Increased activity of the rectus abdominis bilaterally therefore potentially helps stabilize the pelvis and lumbar spine and provides a more stable fixation point for the hip flexor muscles, principally the iliopsoas and rectus femoris.

HIP

HIP EXTENSORS:

- Activation of the gluteus maximus begins at late swing and serves two purposes—initiating hip extension and preparing the musculature for weight acceptance at the beginning of stance.
- The gluteus maximus remains active from heel contact to mid stance (i.e., first 30% of the gait cycle) to support the weight of the body and produce hip extension. Strong activation of the gluteus maximus when the foot is firmly planted also assists indirectly with knee extension.

- During the swing phase, the gluteus maximus is largely inactive until late swing, when a modest activation is needed to first decelerate the flexing hip and then initiate its extension.
- The hamstring muscles are active during the first 10% of the gait cycle, likely for similar reasons as the gluteus maximus to extend the hip and support the weight of the body.

HIP FLEXORS:

- The iliopsoas becomes active well before toe off and remains so through early swing.
- The activation at between 30% and 50% of the gait cycle is likely initially eccentric, as the hip is extending at that time, followed by a concentric action to initiate hip flexion just before toe off.
- Despite the continued hip flexion into late swing, the hip flexor muscles are active only in the first 50% of the swing phase.

- The rectus femoris also acts as a hip flexor and therefore assists with the aforementioned actions.
- The key roles of the hip flexors are to advance the lower extremity forward during swing in preparation for the next step and to lift the lower extremity to allow for toe clearance during swing.
- The sartorius, another anterior muscle of the hip, is also active as a hip flexor from toe off until mid swing.

HIP ABDUCTORS:

- Whereas hip flexors and extensors have their primary role in the sagittal plane, the hip abductors—gluteus medius, gluteus minimus, and tensor fascia lata—stabilize the pelvis in the frontal plane.
- The gluteus medius is active toward the very end of the swing phase in preparation for heel contact.

- The gluteus medius and minimus, the two primary hip abductors, are most active during the first 40% of the gait cycle, especially during single-limb support.
- The primary function of the abductors is to control the slight lowering of the contralateral pelvis on the side of the swing limb.
- After this eccentric action, these muscles act concentrically to initiate the relative abduction of the hip that occurs in later stance.

HIP ADDUCTORS AND HIP ROTATORS:

- The hip adductors show two bursts of activity during gait. The first burst occurs at heel contact and the second just after toe off.
- The initial burst of activity most likely serves to stabilize the hip through co-activation with the hip extensors and hip abductors.
- The second burst of activity, after toe off, likely assists with initiating hip flexion.

- The hip internal rotators (tensor fascia lata, gluteus minimus, and anterior fibers of the gluteus medius) are active throughout much of the stance phase.
- During this time, these internal rotators move the contralateral side of the pelvis forward in the horizontal plane, thereby assisting with advancement of the swing limb.
- Eccentric activation of the external rotators may be especially important to the control of the internal rotation of the lower limb in early stance

KNEE

KNEE EXTENSORS:

- As a group, the quadriceps is active in the very late stage of the swing phase in preparation for heel contact.
- The major burst of activity, however, occurs shortly after heel contact. The function of the quadriceps at this time is to control the knee flexion that takes place in the first 10% of the gait cycle.
- The quadriceps then acts concentrically to extend the knee and support the weight of the body during mid stance.

KNEE FLEXORS:

- The hamstrings are most active from a period just before to just after heel contact. Before heel contact, the hamstrings decelerate knee extension in preparation for the placement of the foot on the ground.
- During the initial 10% of stance, the hamstrings are active to assist with hip extension and to provide stability to the knee through co-activation.

ANKLE AND FOOT

TIBIALIS ANTERIOR:

- The tibialis anterior has two periods of activity.
- At heel contact, a strong eccentric activation is present to decelerate the passive plantar flexion of the ankle caused by the weight of the body being applied on the most posterior section of the calcaneus.

- The second period of activation of the tibialis anterior occurs during the swing phase.
- The purpose of this activation is to produce sufficient dorsiflexion of the ankle to clear the toes from the ground.
- Extreme weakness of the tibialis anterior and the other ankle dorsiflexors typically results in a “drop foot” during the swing phase.

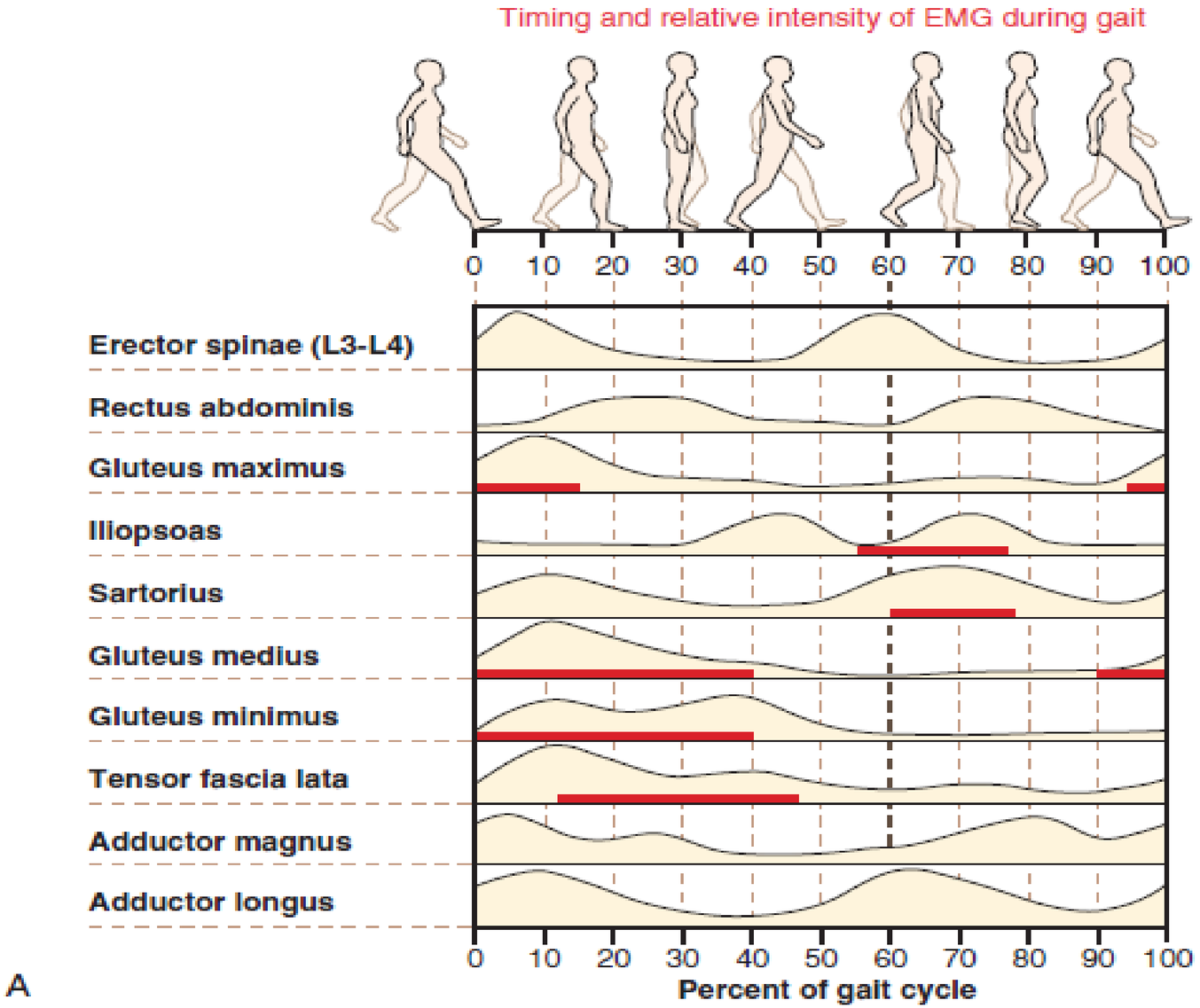
EXTENSOR DIGITORUM AND EXTENSOR HALLUCIS LONGUS:

- Similar to the tibialis anterior, the extensor digitorum longus and extensor hallucis longus decelerate plantar flexion of the ankle at heel contact.
- During swing, the toe extensors assist with dorsiflexion of the ankle and extend the toes to ensure that the toes clear the ground.

ANKLE PLANTAR FLEXORS:

- The soleus and gastrocnemius are active throughout most of the stance phase, with the notable exception of the first 10% of the gait cycle.
- During this period, plantar flexion of the foot is controlled by an eccentric action of the ankle dorsiflexors. From about 10% of the gait cycle to heel off (30% to 40% of the gait cycle), the ankle plantar flexors are active eccentrically to control the forward movement of the tibia and fibula relative to the talus (i.e., ankle dorsiflexion).

- The major burst of activity of the ankle plantar flexors occurs near heel off and decreases rapidly to near zero at toe off.
- During this brief period, shortening of the muscles creates an ankle plantar flexion torque that participates in the forward propulsion of the body. This action is referred to as *push off*.
- The other plantar flexors of the ankle (tibialis posterior, flexor hallucis longus, flexor digitorum longus, and fibularis longus and brevis) assist the gastrocnemius-soleus group.


Timing and relative intensity of EMG during gait
0 10 20 30 40 50 60 70 80 90 100
Erector spinae (L3-L4)
Rectus abdominis
Gluteus maximus
Iliopsoas
Sartorius
Gluteus medius
Gluteus minimus
Tensor fascia lata
Adductor magnus
Adductor longus
0 10 20 30 40 50 60 70 80 90 100
Percent of gait cycle

A

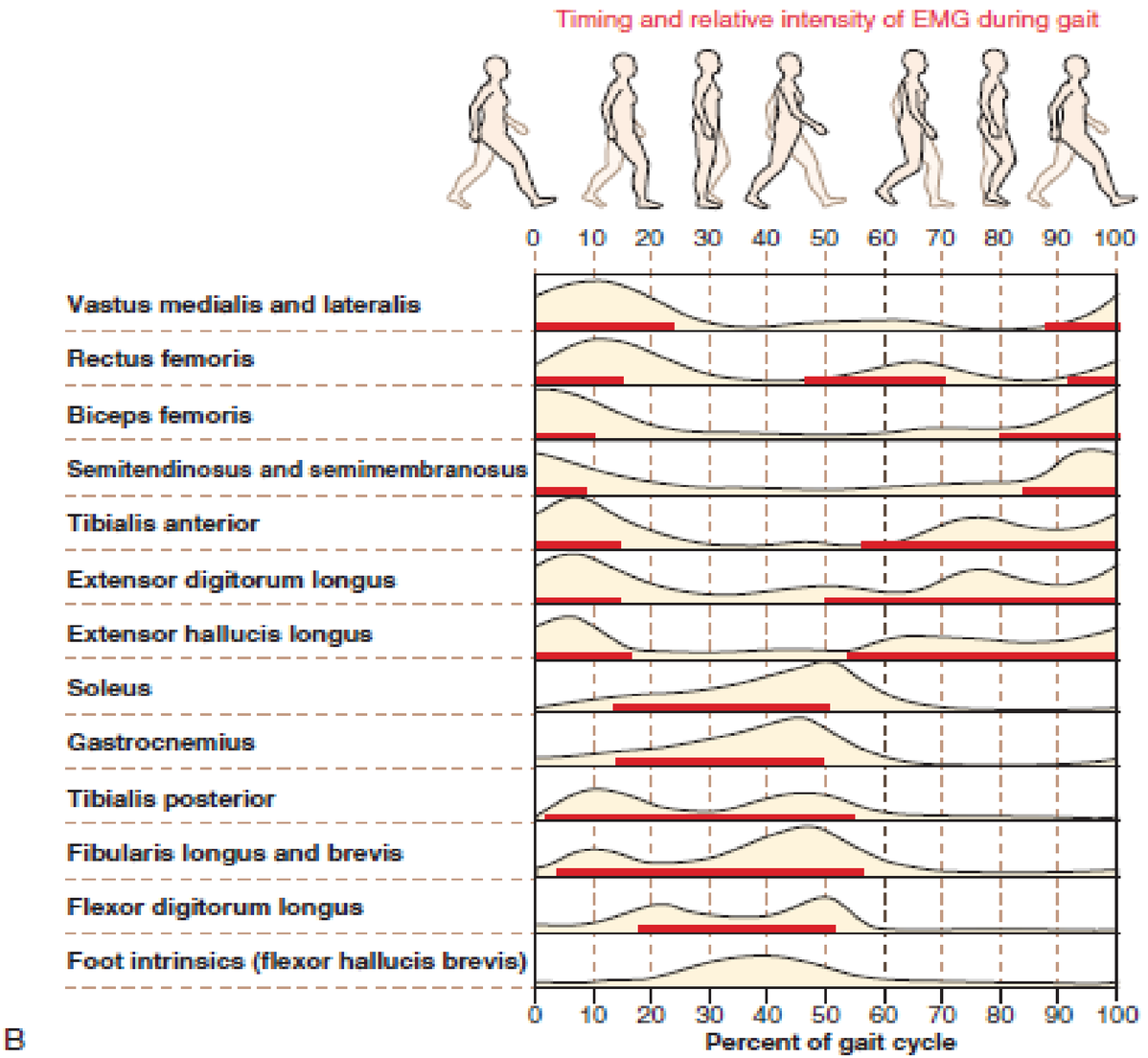


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FIG. 15.29 cont'd.

UPPER EXTREMITIES

- During the forward portion of arm swinging, the following medial rotators are active: **subscapularis, teres major,** and **latissimus dorsi muscles.**
- In backward swing, the **middle** and **posterior deltoid muscles** are active throughout, and the **latissimus dorsi** and **teres major muscles** are active only during the first portion of backward swing.
- The **supraspinatus, trapezius,** and **posterior** and **middle deltoid muscles** are active in both backward and forward swing.

PATHOLOGICAL GAIT

- Some pathological changes may cause the improper gait pattern and abnormality in the gait.
    - i. Neurological gait
    - ii. Muscular weakness gait
    - iii. Joint or muscular limitation gait
    - iv. Leg length discrepancy gait
    - v. Painful gait.

NEUROLOGICAL GAIT

PARKINSON GAIT:

- The gait pattern is said to be shuffling gait or festinant gait or festinating gait.
- The patient adopts the flexed posture of neck, trunk, hip and knee due to the rigidity of the muscles. Because of the flexed posture, the COG falls anteriorly.
- The initiation of movement also difficult by the patient to chase the COG and to keep it in same position and regain balance, the patient tends to have the rapid shuffling gait.

- The patient will have short steps, lack of heel strike and toe off, loss of arm swinging and lack of pelvic rotation.
- In this gait heel strike is absent, so toe strikes first hence called as Toe-heel gait.
- This type of gait may be seen in Parkinson's disease, Wilson's disease, cerebral atherosclerosis.

HEMIPLEGIC GAIT:

- The patient rotates the hip sideways during the swing phase due to the hip flexor tightness and places the foot in flattened manner or toe first before heel strike.
- There is absence of heel strike due to the plantar flexor contracture.
- Upper limb is flexed in the affected side. The steps are lengthened towards the affected side comparatively with the unaffected side. Otherwise called as circumduction gait.

ATAXIC GAIT: There are two types of ataxic gaits are seen in cerebellar and sensory ataxia.

CEREBELLAR ATAXIA:

- Hypotonia and the ataxic gait are the main features of the cerebellar lesion. There will be lacking of the coordinated movements. The gait pattern resembles like ‘drunker gait’.
- The patient sway here and there without stability and balance. This gait is otherwise called as ‘reeling gait’.

SENSORY ATAXIA:

- It can be seen in tabes dorsalis, diabetes mellitus, leprosy and syringomyelia.
- The patient raises the foot in the air, through forward in uncertain manner and stamp on the floor slowly due to the lack of kinesthetic sensation.
- The gait pattern looks like ‘space walk’.

SCISSORING GAIT (CROSSED-LEG GAIT):

- It is seen in the cerebral palsy and in exaggerated form of paraplegia.
- The legs are crossing each other while walking due to the adductor tightness.
- The knee might may be flexed in the spastic diplegia is called as ‘couch gait’. During the swing phase of one lower extremity cross the stance leg.

MUSCULAR WEAKNESS GAIT

GLUTEUS MEDIUS GAIT:

- One side gluteus medius paralysis results in Trendelenburg gait.
- Both the side paralysis results in duck walking.

TRENDELENBURG'S GAIT:

- During the swing phase of one lower extremity the opposite side hip abductors help to prevent the tilting of the pelvis of the swinging extremity.
- Weakness or paralysis of right side gluteus medius results in pelvic drop over the left side while going for the swing phase.
- So, the patient while walking bends his trunk towards the paralyzed side, i.e. opposite to the dropping gait.

DUCK WALKING GAIT:

- When both the abductors of the hip paralyzed the patient bends his trunk laterally towards the stance phase.
- Lower extremity, whenever the same side lower extremity goes for swing phase. To prevent the over dropping of the pelvis and to clear the foot from the ground, this adjustment made by the patient.
- Both side lurching of the trunk happens while walking is called as 'duck walking' or 'waddling gait'.

GLUTEUS MAXIMUS GAIT:

- The gluteus maximus causes posterior pelvic tilting gait and shifting the COG towards the stance hip. While the body propels forward during the mid-stance phase if the gluteus maximus paralysed the trunk is lurched posteriorly to cause the posterior tilting and shifting the COG towards to stance hip.
- So, while walking forward and backward movement of the trunk occurs is called as ‘rocking horse gait’.

QUADRICEPS (HAND TO KNEE GAIT):

- This type of gait is possible typically in the patients with quadriceps paralysis.
- During the mid-stance, to transmit the weight on the stance lower leg extremity, the knee should be locked.
- This locking is not possible if the quadriceps is paralysed so that the patient himself is locking the knee by placing his hands above the knee joint.

HIGH STEPPING GAIT (FOOT DROP GAIT):

- During the heel strike the ankle goes for dorsiflexion. If the dorsiflexors are paralyzed, the plantar flexors overacts.
- During heel strike due to foot drop the toes goes and contact the ground first, to avoid this the patient flexes his hip and raises the foot and slap on the floor forcibly.
- It is seen in some neurological conditions like polyneuritis, muscular dystrophies and peroneal muscle atrophy.

- In some exception case, the patient started walking with the dragging the toes on the floor without flexing hip and raising foot called as toe ‘dragging gait’.

GENU RECURVATUM GAIT:

- If the hamstring muscles paralyses, the knee goes for hyperextension in the mid-stance while transmitting weight through the stance leg, the knee goes for hyperextension due to the lack of counteraction of the hamstring.
- And also during the late stage of swing phase slowering of the swing due to the hamstring paralysis and the knee will snap into extension. It is commonly seen in polio.

JOINT OF MUSCULAR LIMITATION GAIT

TOE TIP GAIT:

- Foot remains in plantar flexion due to the contracture of the plantar flexor or may be due to paralysis of dorsiflexors so that the patient walks on the toe tip and the ball of the metatarsals.
- This type of gait can be seen in some neurological conditions like DMD and spastic diplegia.

CALCANEAL GAIT:

- Contracture of dorsiflexor or paralysis of plantar flexor may cause the stable dorsiflexed foot.
- So, while walking there is absence of foot flat, mid-stance, toe-off stages. Instead of that the patient walks with heel or the calcaneum.
- This type of gait is said to be calcaneal gait.

HIP FLEXOR CONTRACTURE GAIT:

- The hip flexor plays main role to propel the swinging extremity forwards. If it is contracted or hip joint is ankylosed the flexion movement will be restricted.
- To compensate that the patient hikes his pelvis and laterally half-circumducts his hip and propels forwards as well as due to hip flexor contracture, hip extension is also restricted to compensate that the patients do more anterior pelvic tilt and lordosis to swing the extremity forwards.

STIFF KNEE GAIT:

- Normally, during the early stage of swing phase the knee should go for flexion to clear the foot from the ground.
- If the knee is stiff the patient hikes his hip and clears the foot from the floor and swing sideways with hip circumduction of abduction to propel the limb forward to reach the heel strike.
- This type of gait is called as ‘Circumduction gait’ or ‘hip abductor gait’.

LEG LENGTH DISCREPANCY GAIT

- When the leg length difference is half inch it can be negligible and it may be compensated by pelvic tilt while walking.
- If the shortening of leg goes up to one and half inch it can be adjusted with slight equines position, meanwhile if the shortening is more than two-inch leads to marked pelvic tilt and equines deformity at the foot.
- This type of gait is called as equines gait.

PAINFUL OR ANTALGIC GAIT

- When the patient has pain over the joint of the lower extremity to avoid to stand on the involved side.
- So, the time taken for the stance phase on the involved side shortens, and shortened step length, shortened reciprocal arm swing, shortened stride length, increased velocity of steps also can be noticed.
- The patient limps while transmitting weight over the involved side so it may be called as limping gait.