The ankle and foot joints

9

Objectives

- To identify on a human skeleton the most important bone features, ligaments, and arches of the ankle and foot.

- To draw and label on a skeletal chart the muscles of the ankle and foot.

- To demonstrate and palpate with a fellow student the movements of the ankle and foot and list their respective planes of motion and axes of rotation.

- To palpate the superficial joint structures and muscles of the ankle and foot on a human subject.

- To list and organize the muscles that produce movement of the ankle and foot and list their antagonists.

The complexity of the foot is evidenced by the 26 bones, 19 large muscles, many small (intrinsic) muscles, and more than 100 ligaments that make up its structure.

Support and propulsion are the two functions of the foot. Proper functioning and adequate development of the muscles of the foot and practice of proper foot mechanics are essential for everyone. In our modern society, foot trouble is one of the most common ailments. Poor foot mechanics early in life inevitably leads to foot discomfort in later years.

The fitness revolution that has occurred during the last two decades has resulted in great improvements in shoes available for sports and recreational activities. In the past, a pair of sneakers would suffice for most activities. Now there are basketball, baseball, football, jogging, soccer, tennis, walking, and cross-training shoes. Good shoes are important, but there is no substitute for adequate muscular development, strength, and proper foot mechanics.

Bones

Each foot has 26 bones that collectively form the shape of an arch. They connect with the thigh and the remainder of the body through the fibula and tibia (Figs. 9.1 and 9.2). Body weight is transferred from the tibia to the talus and the calcaneus.

In addition to the talus and calcaneus, there are five other bones in the rear foot known as the tarsals. Between the talus and the three cuneiform bones lies the navicular. The cuboid is located between the calcaneus and the fourth and fifth metatarsals. Distal to the tarsals are the five metatarsals, which in turn correspond to each of the five toes. The toes are known as the phalanges. There are three individual bones in each phalange except for the great toe, which has only two. Each of these individual bones is known as a phalanx.

The distal end of the tibia and fibula are enlarged and protrude horizontally and inferiorly. These bony protrusions, known as malleoli, serve as a sort of pulley for the tendons of the muscles that run directly posterior to them. This bony arrangement increases the mechanical advantage of these muscles in performing their actions of inversion and eversion. The base of the fifth metatarsal is enlarged and prominent to serve as an attachment point for the peroneus brevis and tertius. The posterior surface of the calcaneus is very prominent and serves as the attachment point for the Achilles tendon of the gastrocnemius-soleus complex.

FIG. 9.1 • Right fibula and tibia.

From Anthony CP, Kolthoff NJ: *Textbook of anatomy and physiology*, ed 9, St. Louis, 1975, Mosby.

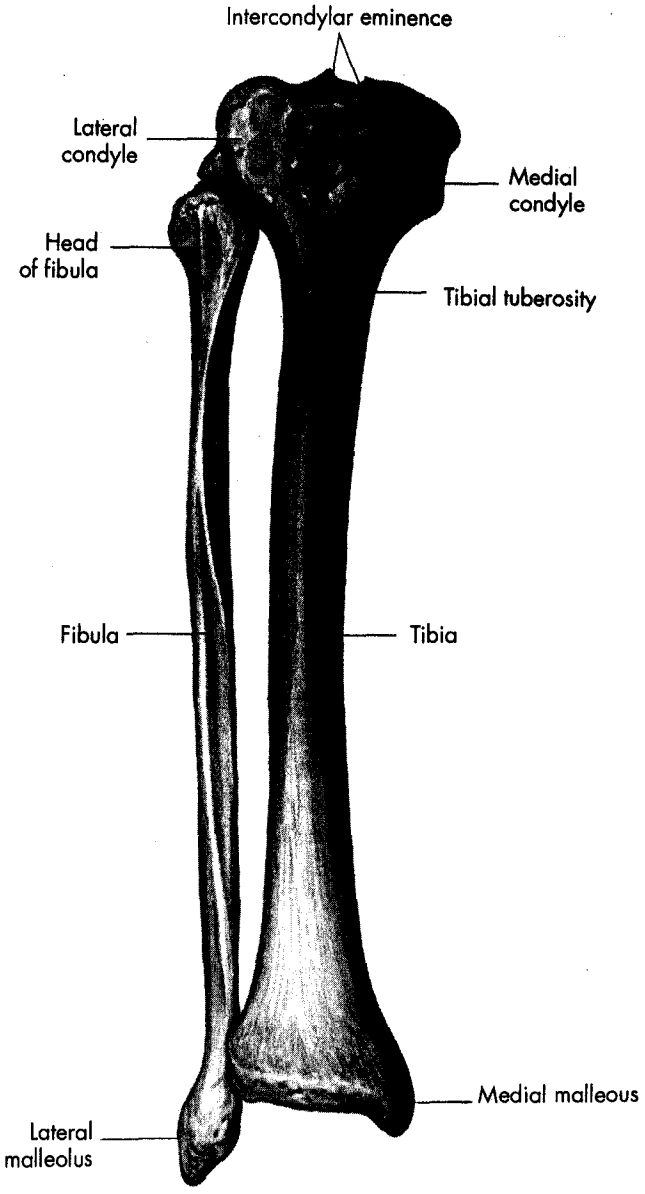
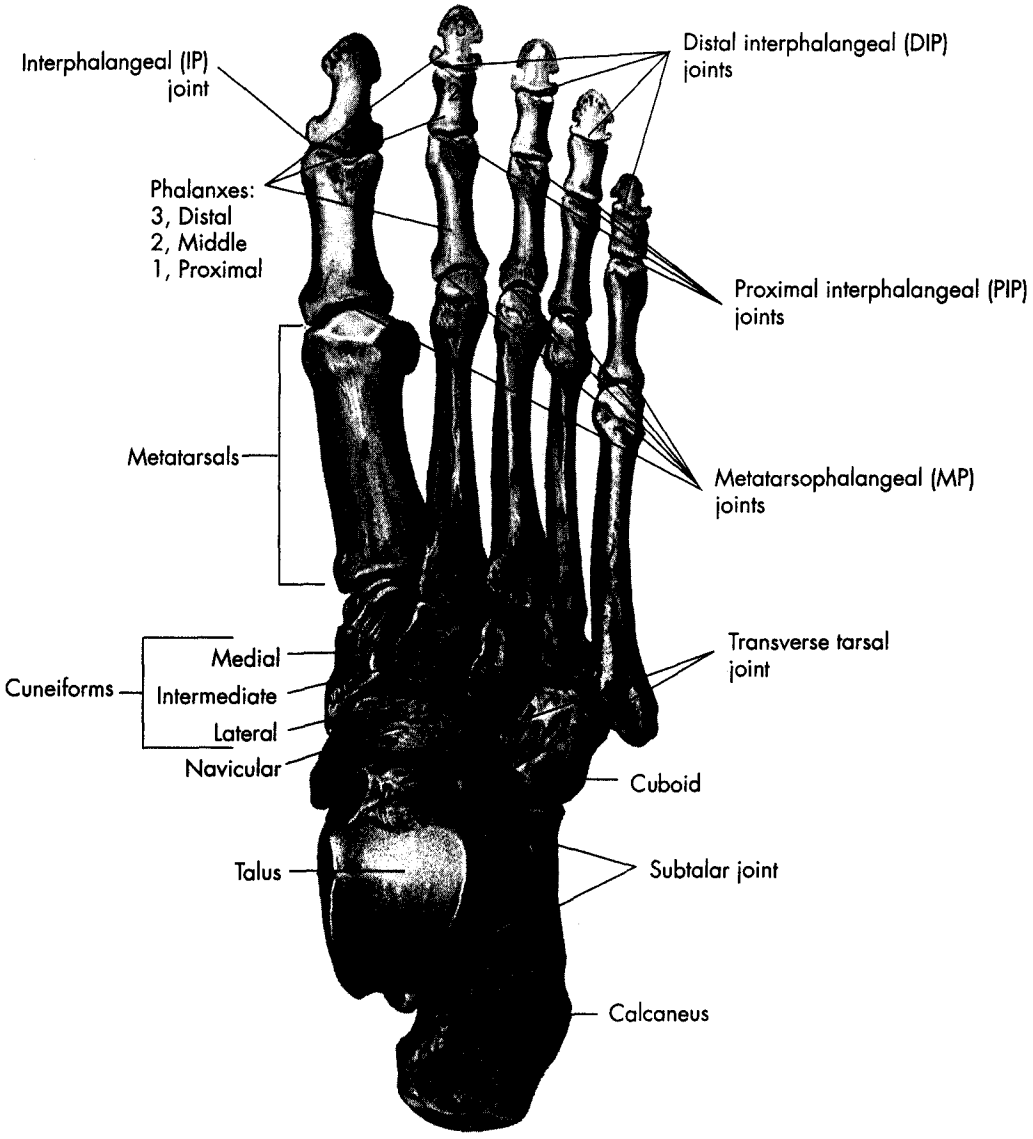


FIG. 9.2 • Right foot.

Modified from Anthony CP, Kolthoff NJ: *Textbook of anatomy and physiology*, ed 9, St. Louis, 1975, Mosby.



Joints

The tibia and fibula form the tibiofibular joint, a syndesmotic amphiarthrodial joint (see Fig. 9.1). The bones are joined at both the proximal and distal tibiofibular joints. In addition to the ligaments supporting both of these joints, there is a strong, dense interosseus membrane between the shafts of these two bones. Although only minimal movement is possible between these bones, the distal joint does become sprained occasionally in heavy contact sports such as football. This injury, a sprain of the syndemosis joint, usually involves the anterior inferior tibiofibular ligament, and may possibly involve the posterior inferior tibiofibular ligament as well.

The ankle joint, technically known as the talocrural joint, is a hinge or ginglymus-type joint (Fig. 9.3). Specifically, it is the joint made up of the talus, the distal tibia, and the distal fibula. The ankle joint allows approximately 50 degrees of plantar flexion and 15 to 20 degrees of dorsiflexion. Greater range of dorsiflexion is possible when the knee is flexed, which reduces the tension of the biarticular gastrocnemius muscle.

Inversion and eversion, although commonly thought to be ankle joint movements, technically occur in the subtalar and transverse tarsal joints. These joints, classified as gliding or arthrodial, combine to allow approximately 20 to 30 degrees of inversion and 5 to 15 degrees of eversion. There is minimal movement within the remainder of the intertarsal and tarsometatarsal arthrodial joints.

The phalanges join the metatarsals to form the metatarsophalangeal joints, which are classified as condyloid-type joints. The metatarsophalangeal (MP) joint of the great toe flexes 45 degrees and extends 70 degrees, whereas the interphalangeal (IP) joint can flex from 0 degrees of full extension to 90 degrees of flexion. The MP joints of the four lesser toes allow approximately 40 degrees of flexion and 40 degrees of extension. The MP joints also abduct and adduct minimally. The proximal interphalangeal (PIP) joints in the lesser toes flex from 0 degrees of extension to 35 degrees of flexion. The distal interphalangeal (DIP) joints flex 60 degrees and extend 30 degrees. There is much variation from joint to joint and from person to person in all of these joints.

Ankle sprains are one of the most common injuries among physically active people. Sprains involve stretching or tearing of one or more ligaments. There are far too many ligaments in the foot and ankle to discuss in this text, but a few of the ankle ligaments are shown in Fig. 9.3. Far and away the most common ankle sprain results from excessive inversion that causes damage to the lateral ligamentous structures, primarily the anterior talofibular ligament and the calcaneofibular ligament. Excessive eversion forces causing injury to the deltoid ligament on the medial aspect of the ankle occur less commonly.

Ligaments in the foot and the ankle have the difficult task of maintaining the position of an arch. All 26 bones in the foot are connected with ligaments. This brief discussion is focused on the longitudinal and transverse arches.

There are two longitudinal arches (Fig. 9.4). The medial longitudinal arch is located on the medial side of the foot and extends from the calcaneus bone to the talus, the navicular, the three cuneiforms, and the proximal ends of the three medial metatarsals. The lateral longitudinal arch is located on the lateral side of the foot and extends from the calcaneus to the cuboid and proximal ends of the fourth and fifth metatarsals. Individual long arches can be high, medium, or low, but a low arch is not necessarily a weak arch.

The transverse arch (see Fig. 9.4) extends across the foot from one metatarsal bone to the other.

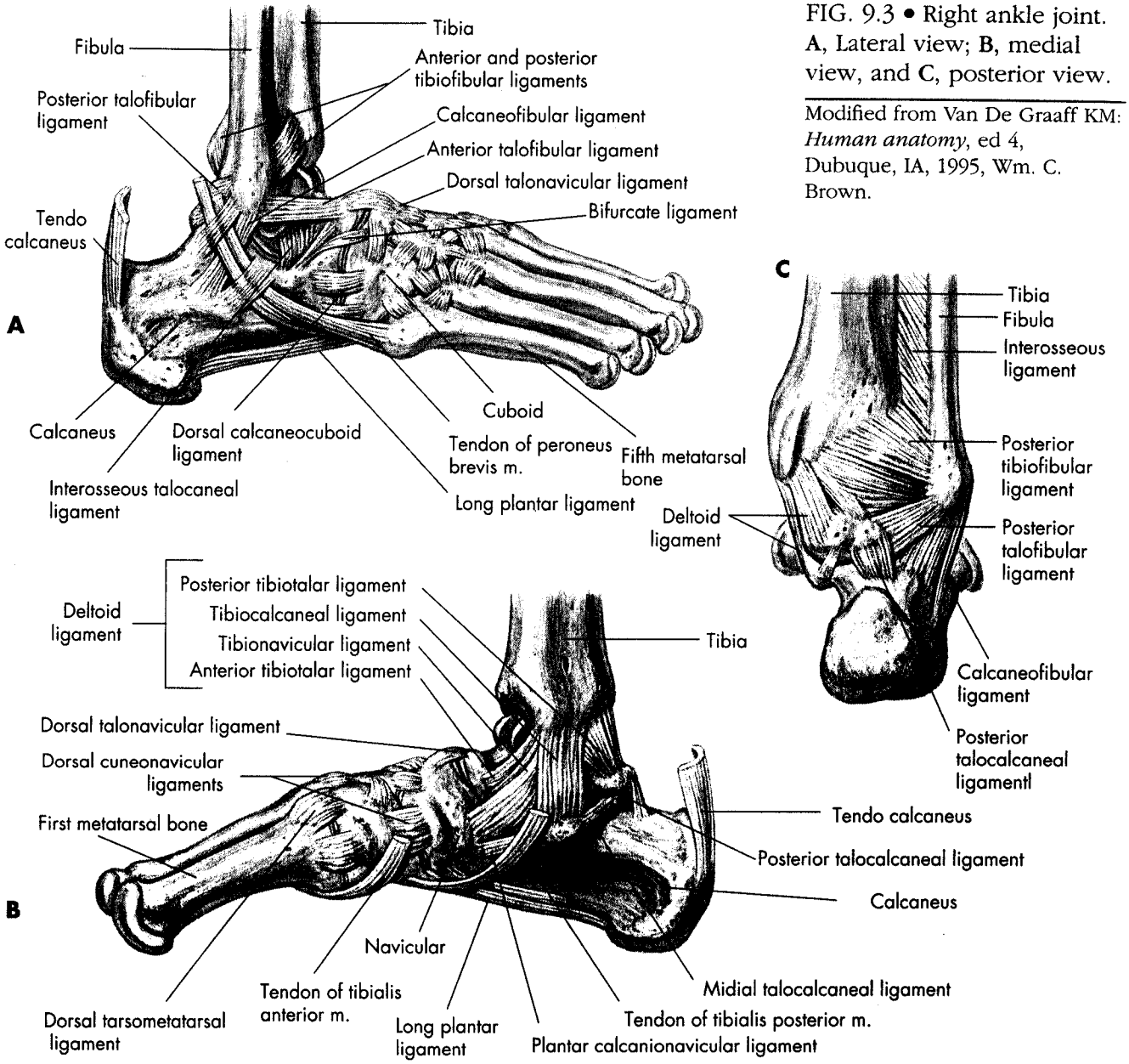


FIG. 9.3 • Right ankle joint. **A**, Lateral view; **B**, medial view, and **C**, posterior view.

Modified from Van De Graaff KM: *Human anatomy*, ed 4, Dubuque, IA, 1995, Wm. C. Brown.

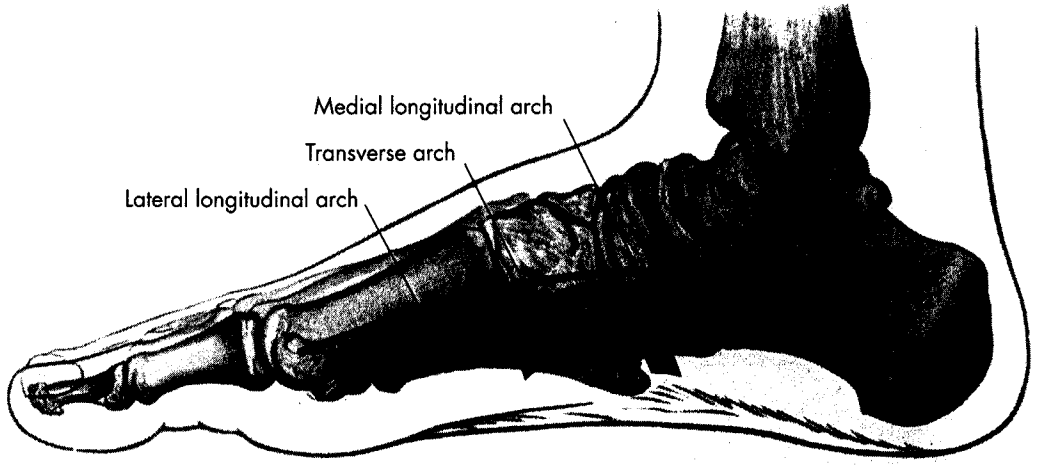


FIG. 9.4 • Longitudinal and transverse arches.

From Anthony CP, Kolthoff NJ: *Textbook of anatomy and physiology*, ed 9, St. Louis, 1975, Mosby.

Ankle and foot muscles

The large number of muscles in the ankle and foot may be easier to learn if grouped according to location and function. In general, the muscles located on the anterior aspect of the ankle and foot are the dorsal flexors. Those on the posterior aspect are plantar flexors. Specifically, the gastrocnemius and the soleus are known as the triceps surae, due to their three heads collectively. Muscles that are evertors are located more to the lateral side, whereas the invertors are located medially.

The lower leg is divided into four compartments, each containing specific muscles (Fig. 9.5). Tightly surrounding and binding each compartment is a dense fascia, which facilitates venous return and prevents excessive swelling of the muscles during exercise. The anterior compartment contains the dorsiflexor group, consisting of the tibialis anterior, peroneus tertius, extensor digitorum longus, and extensor hallucis longus. The lateral compartment contains the peroneus longus and peroneus brevis—the two most powerful evertors. The posterior compartment is divided into deep and superficial compartments. The gastrocnemius, soleus, and plantaris are located in the superficial posterior compartment, while the deep posterior compartment is composed of the flexor digitorum longus,flexor hallucis longus, popliteus, and tibialis posterior. All of the muscles of the superficial posterior compartment are primarily plantar flexors. The plantaris, absent in some humans, is a vestigial biarticular muscle that contributes minimally to ankle plantar flexion. The deep posterior compartment muscles, except for the popliteus, are plantar flexors but also function as invertors.

Due to heavy demands placed on the musculature of the legs in the running activities of most sports, both acute and chronic injuries are common. "Shin splints" is a common term used to describe a painful condition of the leg that is often associated with running activities. This condition is not a specific diagnosis but rather is attributed to a number of different specific musculotendinous injuries. Most often the tibialis posterior, medial soleus, or anterior tibialis is involved.

Additionally, painful cramps caused by acute muscle spasm in the gastrocnemius and soleus occur somewhat commonly and may be relieved through active and passive dorsiflexion. Also, a very disabling injury involves the complete rupture of the strong Achilles tendon, which connects these two plantar flexors to the calcaneus.

NOTE: A number of the ankle and foot muscles are capable of helping to produce more than one movement.

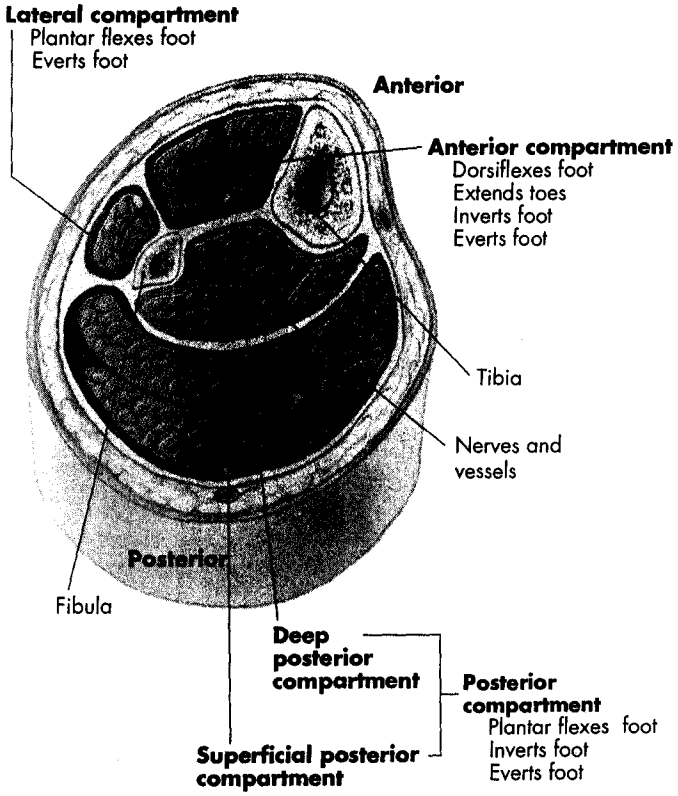


FIG. 9.5 • Cross section of the leg demonstrating the muscular compartments.

From Seeley RR, Stephens TD, Tate P: *Anatomy and physiology*, ed 3, St. Louis, 1995, Mosby.

Ankle and foot muscles

- Plantar flexors
  - Gastrocnemius
  - Flexor digitorum longus
  - Flexor hallucis longus
  - Peroneus longus
  - Peroneus brevis
  - Plantaris
  - Soleus
  - Tibialis posterior
- Evertors
  - Peroneus longus
  - Peroneus brevis
  - Peroneus tertius
  - Extensor digitorum longus
- Dorsiflexors
  - Tibialis anterior
  - Peroneus tertius
  - Extensor digitorum longus (extensor of the lesser toes)
  - Extensor hallucis longus (extensor of the great toe)
- Invertors
  - Tibialis anterior
  - Tibialis posterior
  - Flexor digitorum longus (flexor of the lesser toes)
  - Flexor hallucis longus (flexor of the great toe)

Movements FIG. 9.6

Dorsiflexion (flexion): movement of the top of the ankle and foot toward the anterior tibia bone.

Plantar flexion (extension): movement of the ankle and foot away from the tibia.

Eversion: turning the ankle and foot outward, away from the midline; weight is on the medial edge of the foot.

Inversion: turning the ankle and foot inward, toward the midline; weight is on the lateral edge of the foot.

Toe flexion: movement of the toes toward the plantar surface of the foot.

Toe extension: movement of the toes away from the plantar surface of the foot.

FIG. 9.6 • Movements of the ankle and foot.

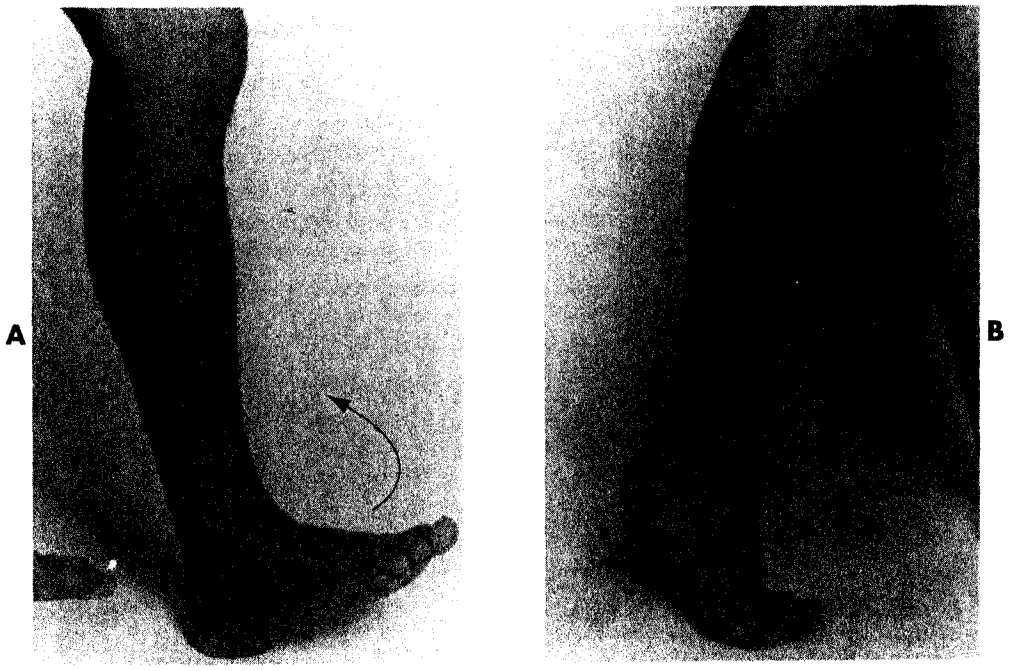
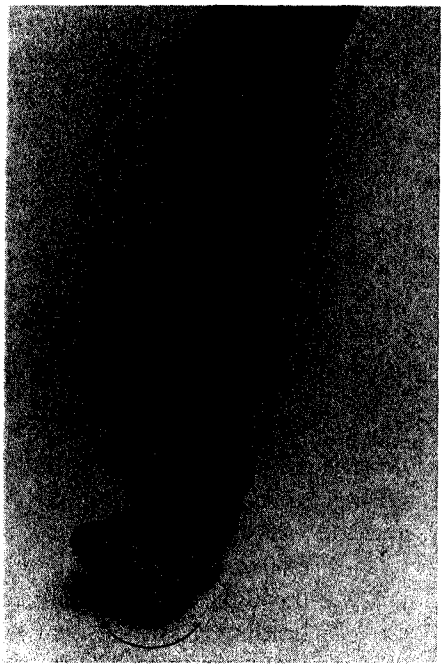


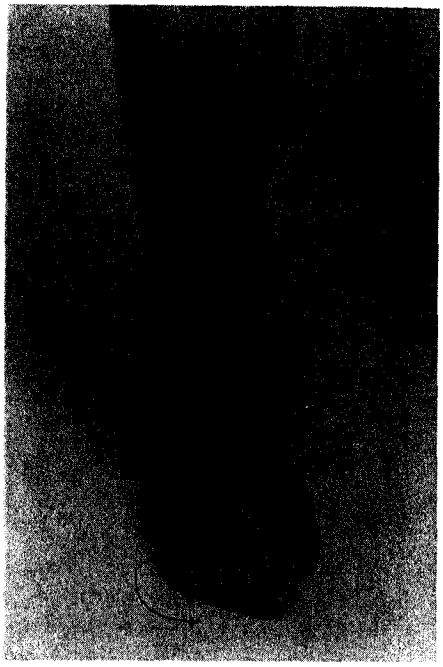
FIG. 9.6 continued • Movements of the ankle and foot.

C



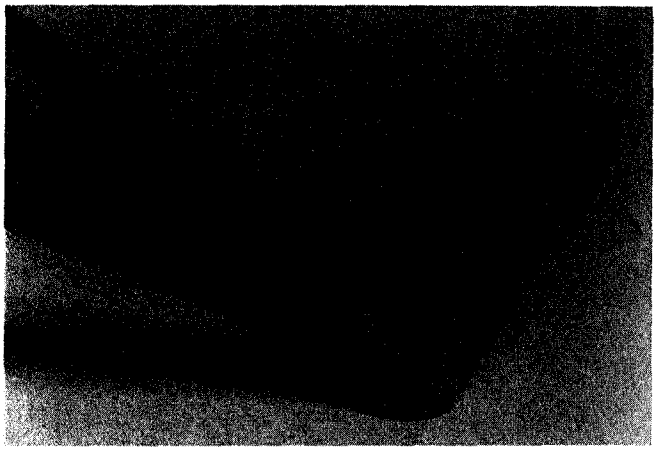
Transverse tarsal and subtalar eversion

D



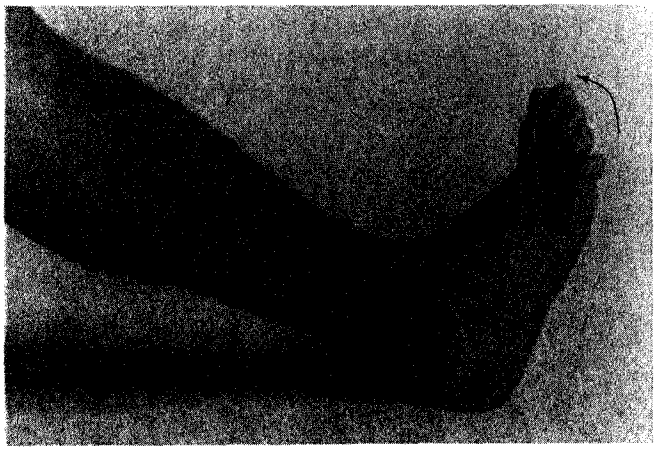
Transverse tarsal and subtalar inversion

E



Flexion of the toes

F



Extension of the toes

Gastrocnemius muscle FIG. 9.7

(gas-trok-ne'mi-us)

Origin

Medial head: posterior surface of the medial femoral condyle.

Lateral head: posterior surface of the lateral femoral condyle.

Insertion

Posterior surface of the calcaneus (Achilles tendon).

Action

Plantar flexion of the ankle.

Flexion of the knee.

Palpation

Easiest muscle in the lower extremity to palpate; upper posterior aspect of the lower leg.

Innervation

Tibial nerve (S1-2).

Application, strengthening, and flexibility

Because the gastrocnemius is a biarticular muscle, it is more effective as a knee flexor if the ankle is dorsiflexed and more effective as a plantar flexor of the foot if the knee is held in extension. This is observed when one sits too close to the wheel in driving a car, which significantly shortens the entire muscle, reducing its effectiveness. When the knees are bent, the muscle becomes an ineffective plantar flexor, and it is more difficult to depress the brakes. Running, jumping, hopping, and skipping exercises all depend significantly on the gastrocnemius and soleus to propel the body upward and forward. Heel-raising exercises with the knees in full extension and the toes resting on a block of wood are an excellent way to strengthen the muscle through the full range of motion. By holding a barbell on the shoulders, the resistance may be increased.

The gastrocnemius may be stretched by performing a wall push-up, which involves standing and placing both palms on a wall about three feet away and leaning into the wall. The feet should be pointed straight ahead and the heels should remain on the floor. The knees should remain fully extended throughout the exercise to accentuate the stretch on the gastrocnemius.

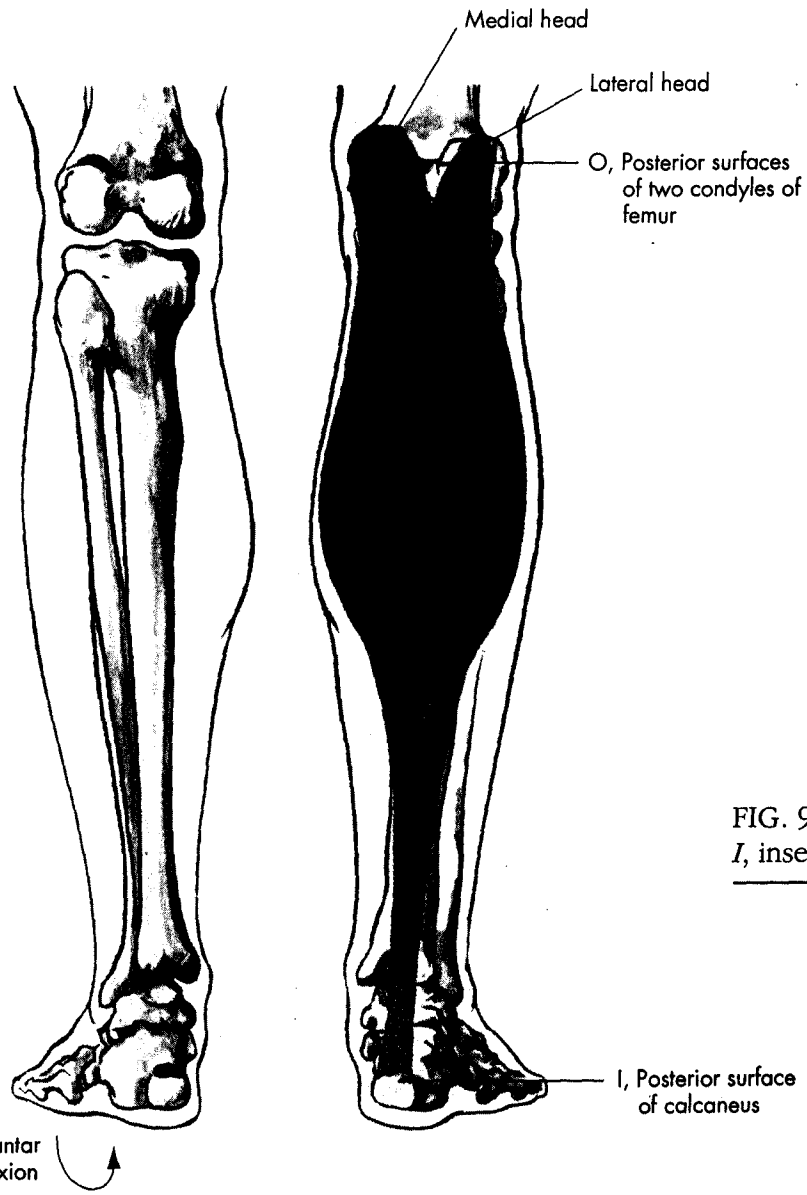


FIG. 9.7 • Gastrocnemius muscle. *O*, Origin; *I*, insertion.

Soleus muscles FIG. 9.8

(so'le-us)

Origin

Posterior surface of the proximal fibula and proximal two-thirds of the posterior tibial surface.

Insertion

Posterior surface of the calcaneus (Achilles tendon).

Action

Plantar flexion of the ankle.

Palpation

Under the gastrocnemius muscle on the lateral side of the lower leg.

Innervation

Tibial nerve (S1-2).

Application, strengthening, and flexibility

The soleus muscle is one of the most important plantar flexors of the ankle. Some anatomists believe that it is nearly as important in this movement as the gastrocnemius. This is especially true when the knee is flexed. When a person rises up on his or her toes, the soleus muscle can plainly be seen on the outside of the lower leg if one has exercised the legs extensively, as in running and walking.

The soleus muscle is used whenever the ankle plantar flexes. Any movement with body weight on the foot with the knee flexed or extended calls it into action. When the knee is flexed slightly, the effect of the gastrocnemius is reduced, thereby placing more work on the soleus. Running, jumping, hopping, skipping, and dancing on the toes are all exercises that depend heavily on the soleus. It may be strengthened through any plantar flexion exercise against resistance, particularly if the knee is flexed slightly to de-emphasize the gastrocnemius. Heel-raising exercises as described for the gastrocnemius, except with the knees flexed slightly, are one way to isolate this muscle for strengthening. Resistance may be increased by holding a barbell on the shoulders.

The soleus is stretched in the same manner as the gastrocnemius except that the knees must be flexed slightly, which releases the stretch on the gastrocnemius and places it on the soleus. Again it is important to attempt to keep the heels on the floor.

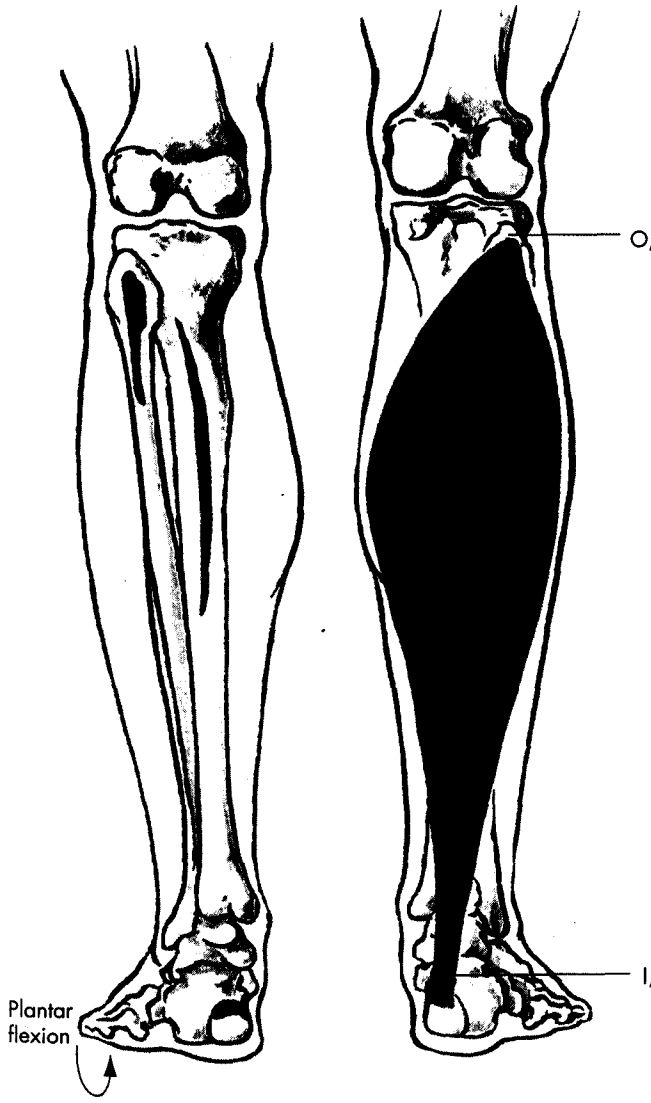


FIG. 9.8 • Soleus muscle. *O*, Origin; *I*, insertion.

Tibialis posterior muscle FIG. 9.9

(tib-i-a'lis pos-te'ri-or)

Origin

Posterior surface of the upper half of the interosseus membrane and adjacent surfaces of the tibia and fibula.

Insertion

Lower inner surfaces of the navicular and cuneiform bones and bases of the second, third, fourth, and fifth metatarsal bones.

Action

Plantar flexion of the ankle.
Inversion of the foot.

Palpation

Cannot be palpated.

Innervation

Tibial nerve (L5, S1).

Application, strengthening, and flexibility

Passing down the back of the leg, under the medial malleolus, then forward to the navicular and medial cuneiform bones, the tibialis posterior muscle pulls down from the underside, and when contracted concentrically, inverts and plantar flexes the foot. "Shin splints" is a slang term frequently used to describe an often chronic condition in which the tibialis posterior, tibialis anterior, and extensor digitorum longus muscles are inflamed. This inflammation is usually a tendonitis of one or more of these structures, but may be a result of stress fracture, periostitis, tibial stress syndrome, or a compartment syndrome. Sprints and long-distance running are common causes, particularly if the athlete has not developed appropriate strength, flexibility, and endurance in the lower leg musculature.

Use of the tibialis posterior muscle in plantar flexion and inversion gives support to the longitudinal arch of the foot. This muscle is generally strengthened by performing heel raises, as described for the gastrocnemius and soleus, as well as inversion exercises against resistance.

The tibialis posterior may be stretched by passively taking the foot into extreme eversion and dorsiflexion while the knee is flexed.

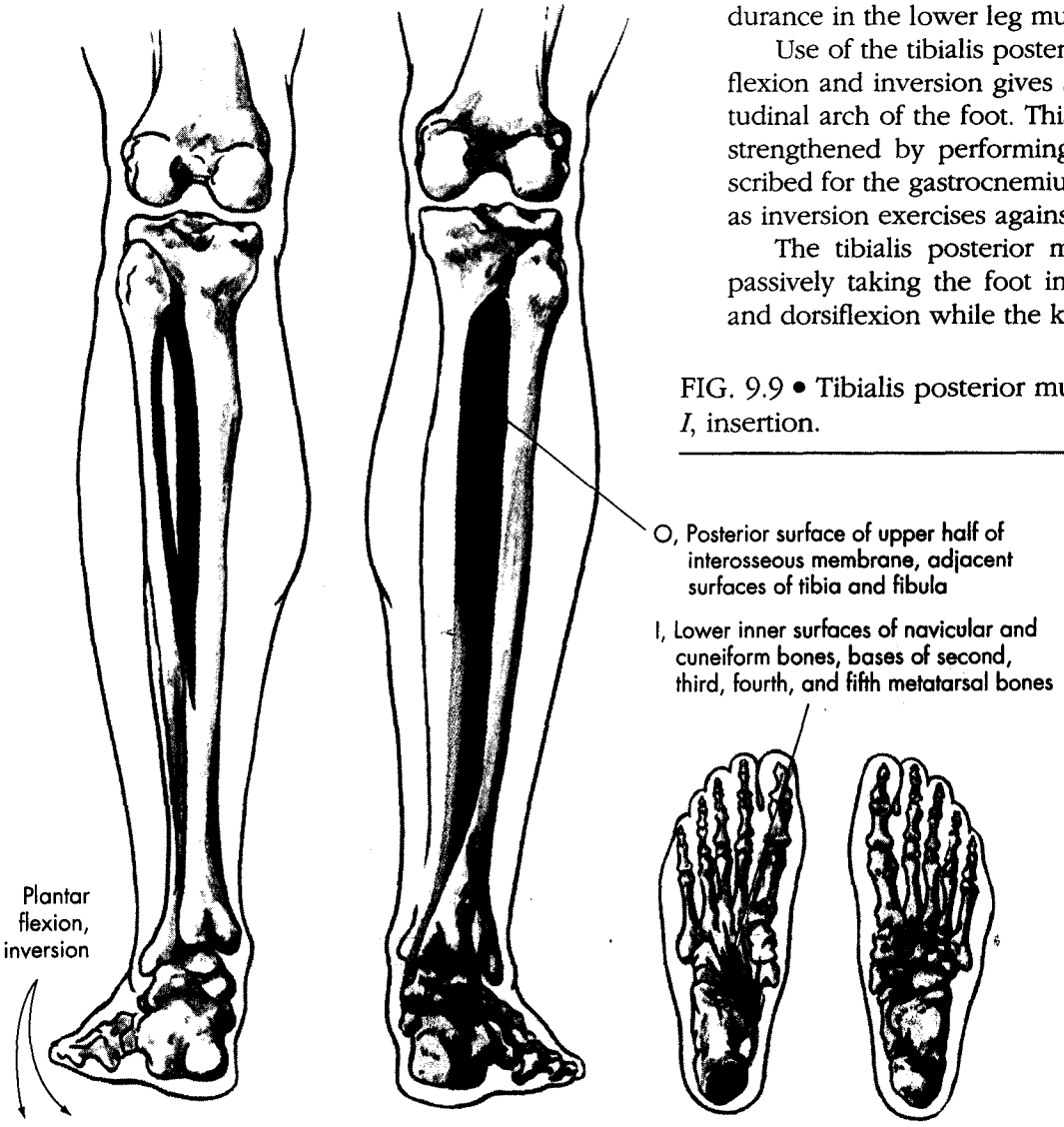


FIG. 9.9 • Tibialis posterior muscle. *O*, Origin; *I*, insertion.

Flexor digitorum longus muscle FIG. 9.10

(fleks'or dij-i-to'rum long'gus)

Origin

Middle third of the posterior surface of the tibia.

Insertion

Base of the distal phalanx of each of the four lesser toes.

Action

Flexion of the four lesser toes.
Plantar flexion of the ankle.
Inversion of the foot.

Palpation

Cannot be palpated.

Innervation

Tibial nerve (L5, S1).

Application, strengthening, and flexibility

Passing down the back of the lower leg under the medial malleolus and then forward, the flexor digitorum longus muscle draws the four lesser toes down into flexion toward the heel as it plantar flexes the ankle. It is very important in helping other foot muscles maintain the longitudinal arch. Walking, running, and jumping do not necessarily call the flexor digitorum longus muscle into action. Some of the weak foot and ankle conditions result from ineffective use of the flexor digitorum longus. Walking barefoot with the toes curled downward toward the heels and with the foot inverted will exercise this muscle. It may be strengthened by performing towel grabs against resistance in which the heel rests on the floor while the toes extend to grab a flat towel and then flex to pull the towel under the foot. This may be repeated numerous times, with a small weight placed on the opposite end of the towel for added resistance.

The flexor digitorum longus may be stretched by passively taking the four lesser toes into extreme extension while the foot is everted and dorsiflexed. The knee should be flexed.

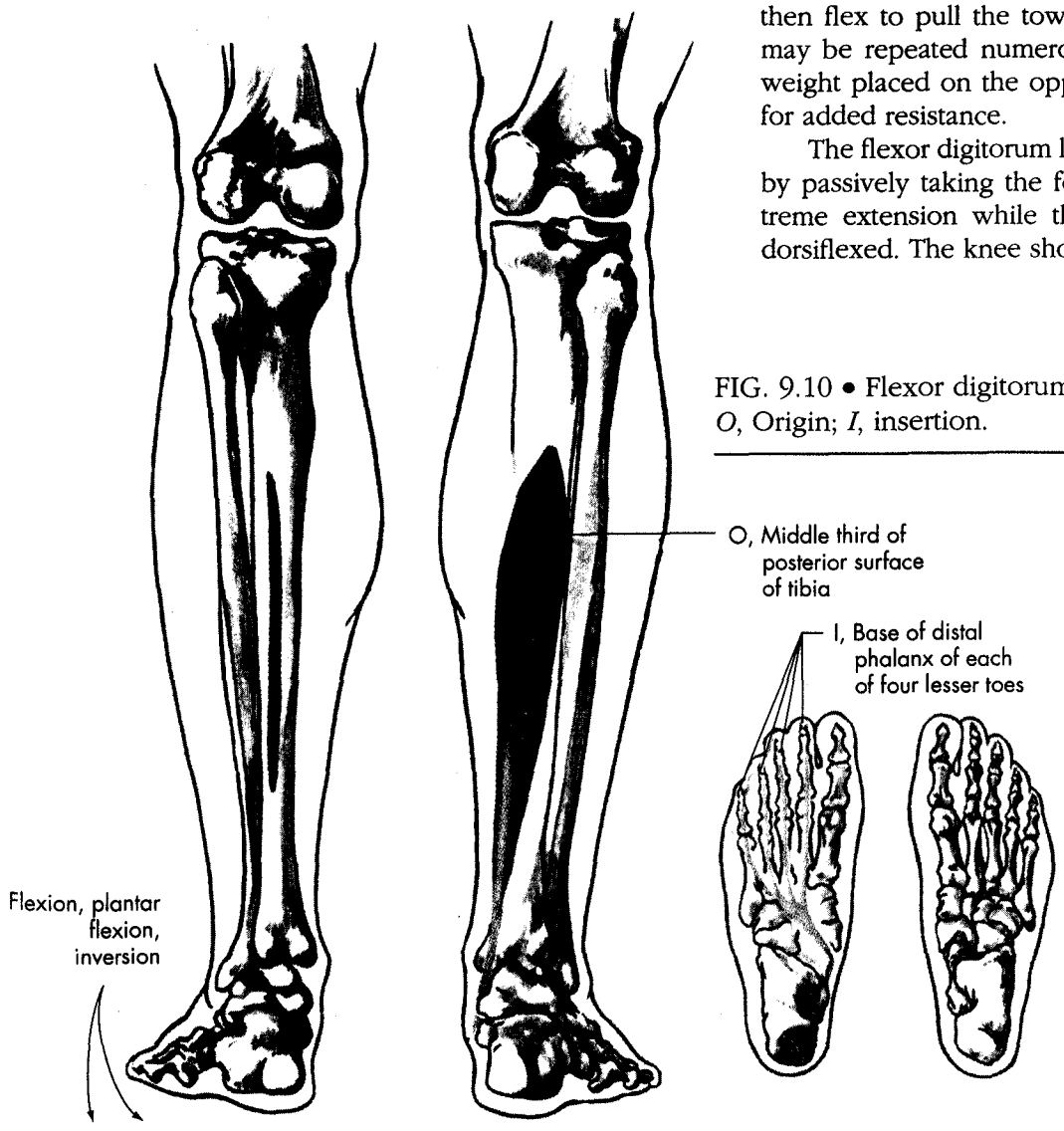


FIG. 9.10 • Flexor digitorum longus muscle. *O*, Origin; *I*, insertion.

Flexor hallucis longus muscle FIG. 9.11

(fleks'or hal-u'sis long'gus)

Origin

Middle two-thirds of the posterior surface of the fibula.

Insertion

Base of the distal phalanx of the big toe, under the surface.

Action

Flexion of the great toe.
Inversion of the foot.
Plantar flexion of the ankle.

Palpation

Anteromedial to the Achilles tendon near the heel.

Innervation

Tibial nerve (L5, S1-2).

Application, strengthening, and flexibility

Pulling from the underside of the great toe, the flexor hallucis longus muscle may work independently of the flexor digitorum longus muscle or with it. If these two muscles are poorly developed, they cramp easily when they are called on to do activities to which they are unaccustomed.

These muscles are used effectively in walking if the toes are used (as they should be) in maintaining balance as each step is taken. Walking "with the toes" rather than "over" them is an important action for them.

When the gastrocnemius, soleus, tibialis posterior, peroneus longus, peroneus brevis, flexor digitorum longus, flexor digitorum brevis, and flexor hallucis longus muscles are all used effectively in walking, the strength of the ankle is evident. If an ankle and a foot are weak, in most cases it is because of lack of use of all the muscles just mentioned. Running, walking, jumping, hopping, and skipping provide exercise for this muscle group. The flexor hallucis longus muscle may be specifically strengthened by performing towel grabs as described for the flexor digitorum longus.

The flexor hallucis longus may be stretched by passively taking the great toe into extreme extension while the foot is everted and dorsiflexed. The knee should be flexed.

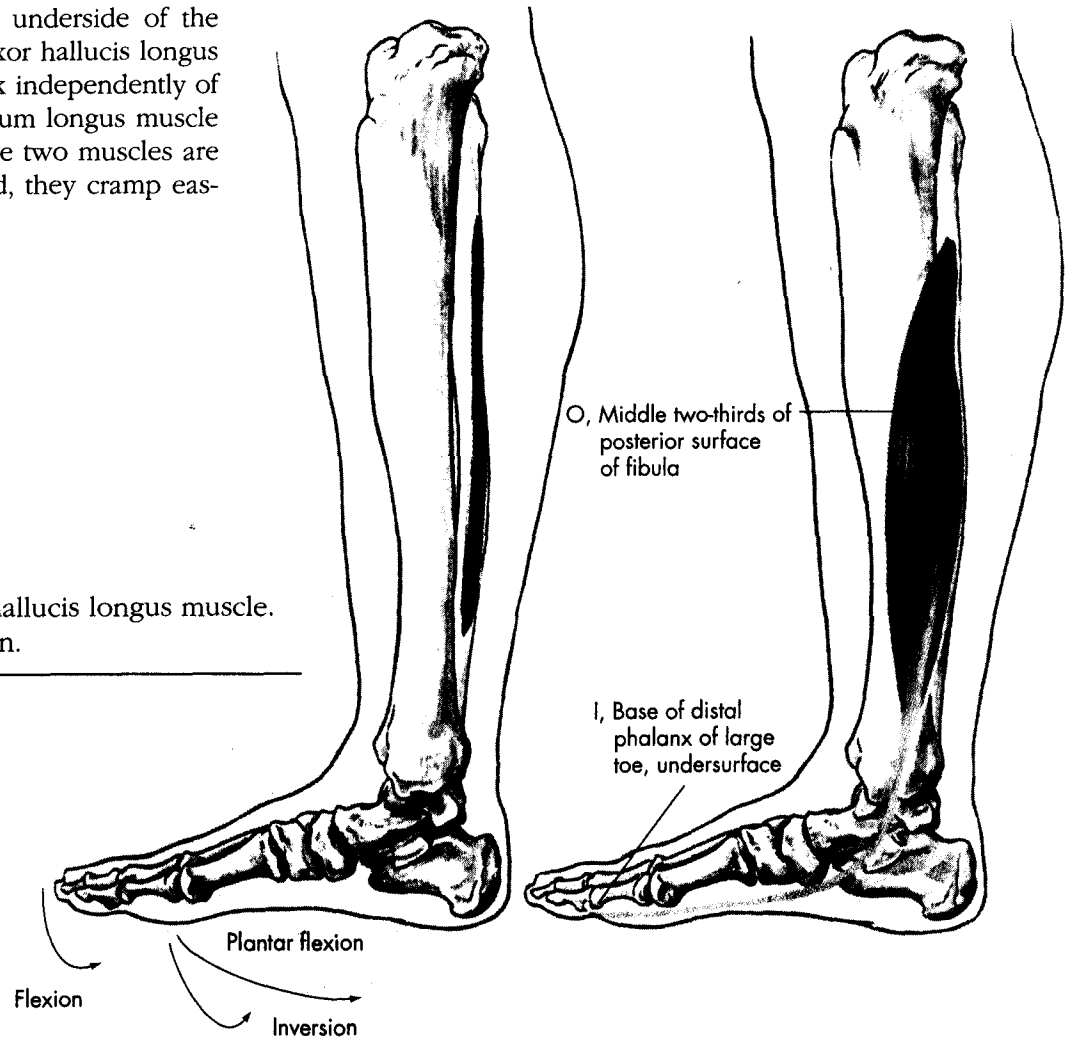


FIG. 9.11 • Flexor hallucis longus muscle. *O*, Origin; *I*, insertion.

Peroneus longus muscle FIG. 9.12

(per-o-ne'us long'gus)

Origin

Head and upper two-thirds of the lateral surface of the fibula.

Insertion

Undersurfaces of the medial cuneiform and first metatarsal bones.

Action

Eversion of the foot.
Plantar flexion of the ankle.

Palpation

Upper lateral side of the tibia; just posterolateral from the tibialis anterior and extensor digitorum longus.

Innervation

Superficial peroneal nerve (L4-5, S1).

Application, strengthening, and flexibility

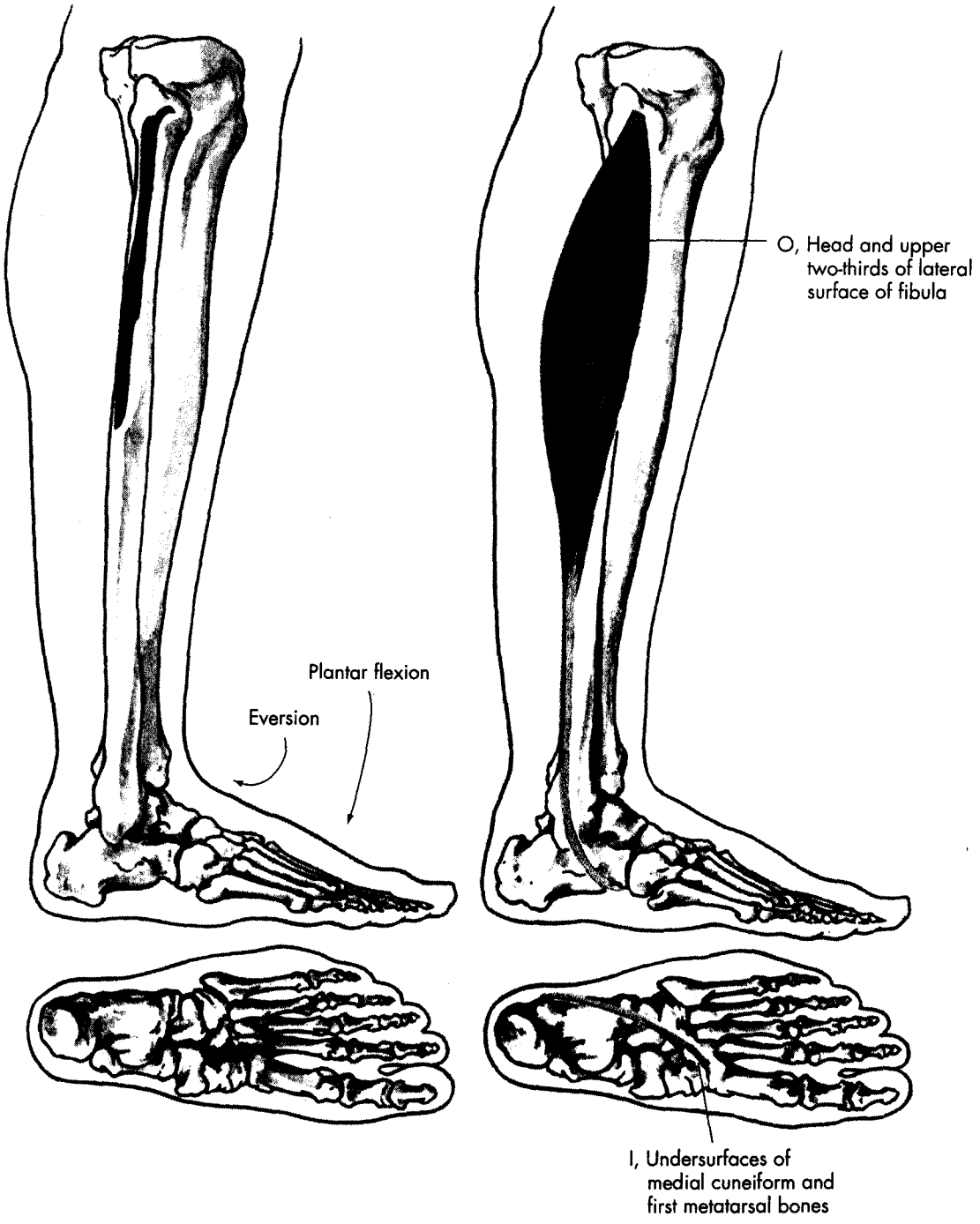
The peroneus longus muscle passes posteroinferiorly to the lateral malleolus and under the foot from the outside to under the inner surface. Because of its line of pull, it is a strong evertor and assists in plantar flexion.

When the peroneus longus muscle is used effectively with the other ankle flexors, it helps bind the transverse arch as it flexes. Developed without the other plantar flexors, it would produce a weak, everted foot. In running, jumping, hopping, and skipping, the foot should be placed so that it is pointing forward to ensure proper development of the group. Walking barefoot or in stocking feet on the inside of the foot (everted position) is the best exercise for this muscle.

Eversion exercises to strengthen this muscle may be performed by turning the sole of the foot outward while resistance is applied in the opposite direction.

The peroneus longus may be stretched by passively taking the foot into extreme inversion and dorsiflexion while the knee is flexed.

FIG. 9.12 • Peroneus longus muscle. *O*, Origin; *I*, insertion.



Peroneus brevis muscle FIG. 9.13

(per-o-ne'us bre'vis)

Origin

Lower two-thirds of the lateral surface of the fibula.

Insertion

Tuberosity of the fifth metatarsal bone.

Action

Eversion of the foot.
Plantar flexion of the ankle.

Palpation

Tendon of the muscle at the proximal end of the fifth metatarsal.

Innervation

Superficial peroneal nerve (L4-5, S1).

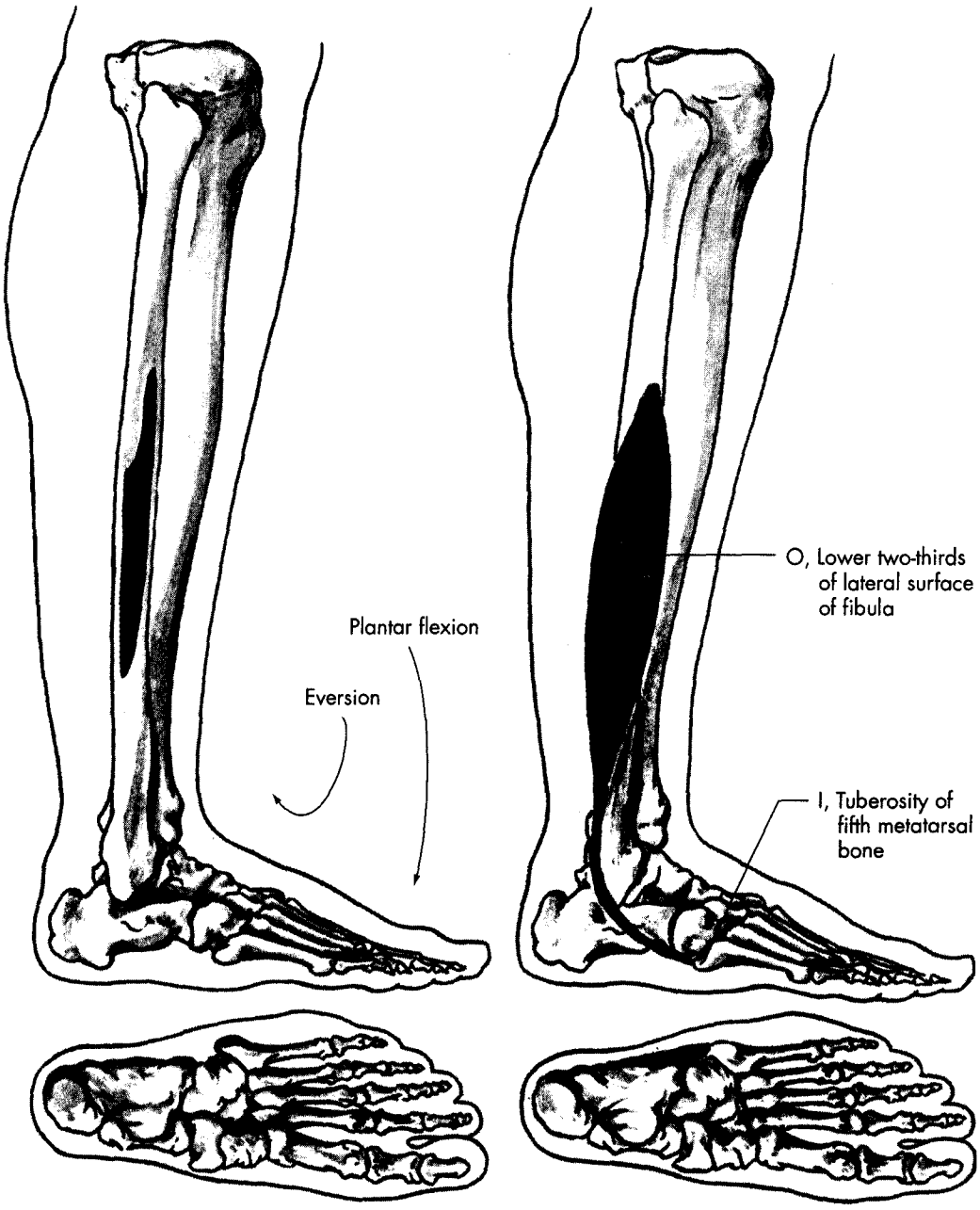
Application, strengthening, and flexibility

The peroneus brevis muscle passes posteroinferiorly to the lateral malleolus to pull on the base of the fifth metatarsal. It is a primary evertor of the foot and assists in plantar flexion. In addition, it aids in maintaining the longitudinal arch as it depresses the foot.

The peroneus brevis muscle is exercised with other plantar flexors in the powerful movements of running, jumping, hopping, and skipping. It may be strengthened in a fashion similar to the peroneus longus by performing eversion exercises, such as turning the sole of the foot outward against resistance.

The peroneus brevis is stretched in the same manner as the peroneus longus.

FIG. 9.13 • Peroneus brevis muscle. *O*, Origin; *I*, insertion.



Peroneus tertius muscle FIG. 9.14

(per-o-ne'us ter'shi-us)

Origin

Distal third of the anterior fibula.

Insertion

Base of the fifth metatarsal.

Action

Eversion of the foot.
Dorsal flexion of the ankle.

Palpation

Lateral to the extensor digitorum longus tendon on the anterolateral aspect of the foot.

Innervation

Deep peroneal nerve (L4-5, S1).

Application, strengthening, and flexibility

The peroneus tertius, absent in some humans, is a small muscle that assists in dorsal flexion and eversion. Some authorities refer to it as the fifth tendon of the extensor digitorum longus. It may be strengthened by pulling the foot up toward the shin against a weight or resistance. Everting the foot against resistance, such as weighted eversion towel drags, can also be used for strength development.

The peroneus tertius may be stretched by passively taking the foot into extreme inversion and plantar flexion.

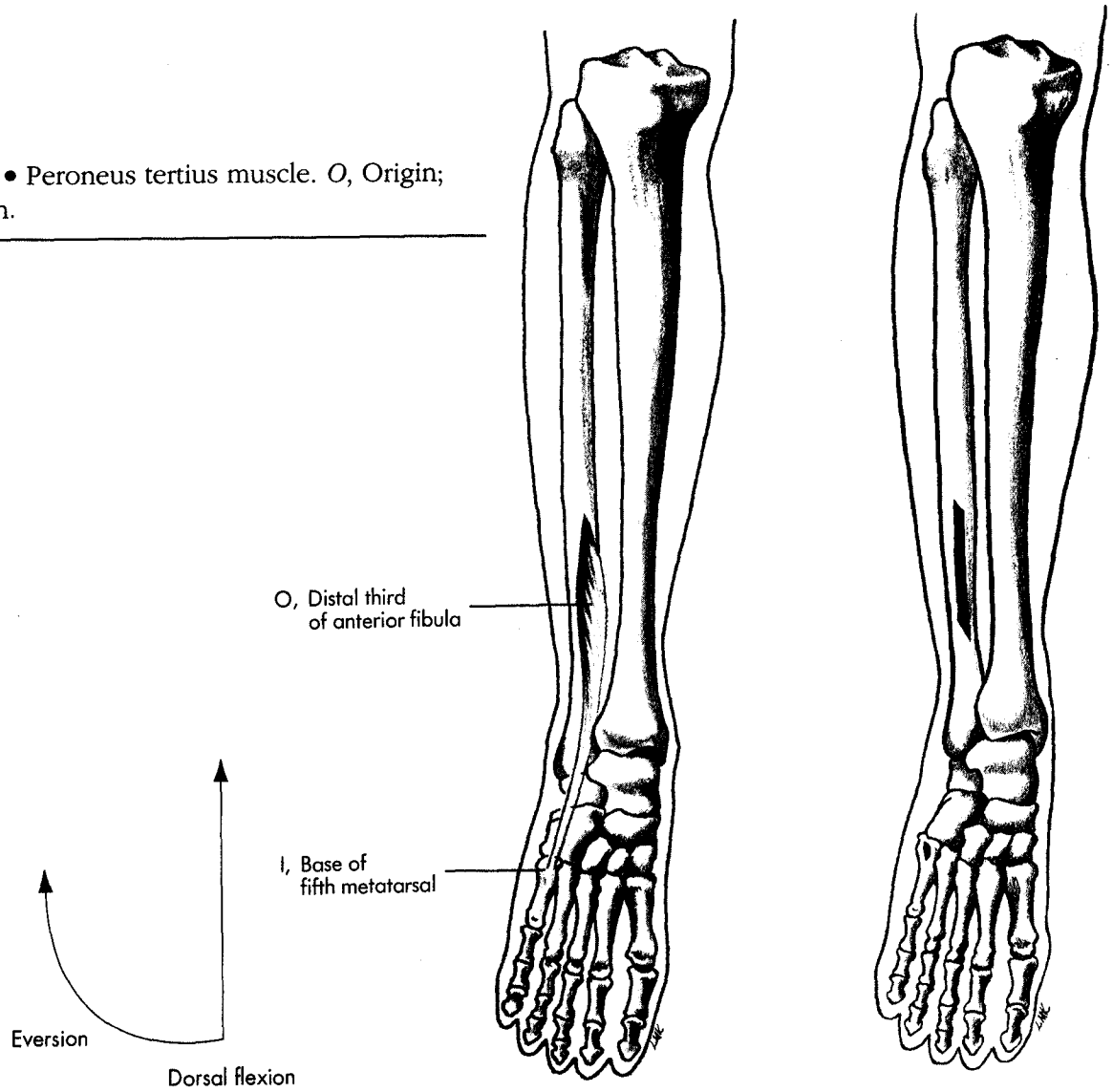


FIG. 9.14 • Peroneus tertius muscle. *O*, Origin; *I*, insertion.

Tibialis anterior muscle FIG. 9.15

(tib-i-a'lis ant-te'ri-or)

Origin

Upper two-thirds of the lateral surface of the tibia.

Insertion

Inner surface of the medial cuneiform and the first metatarsal bone.

Action

Dorsal flexion of the ankle.
Inversion of the foot.

Palpation

First muscle to the lateral side of the tibia.

Innervation

Deep peroneal nerve (L4-5, S1).

Application, strengthening, and flexibility

By its insertion, the tibialis anterior muscle is in a fine position to hold up the inner margin of the foot. However, as it contracts concentrically it dorsiflexes the ankle and is used as an antagonist to the plantar flexors of the ankle. The tibialis anterior is forced to contract strongly when a person ice-skates or walks on the outside of the foot. It strongly supports the long arch in inversion.

Walking barefoot or in stocking feet on the outside of the foot (inversion) is an excellent exercise for the tibialis anterior muscle.

Turning the sole of the foot to the inside against resistance to perform inversion exercises is one way to strengthen this muscle. Dorsal flexion exercises against resistance may also be used for this purpose.

The tibialis anterior may be stretched by passively taking the foot into extreme eversion and plantar flexion.

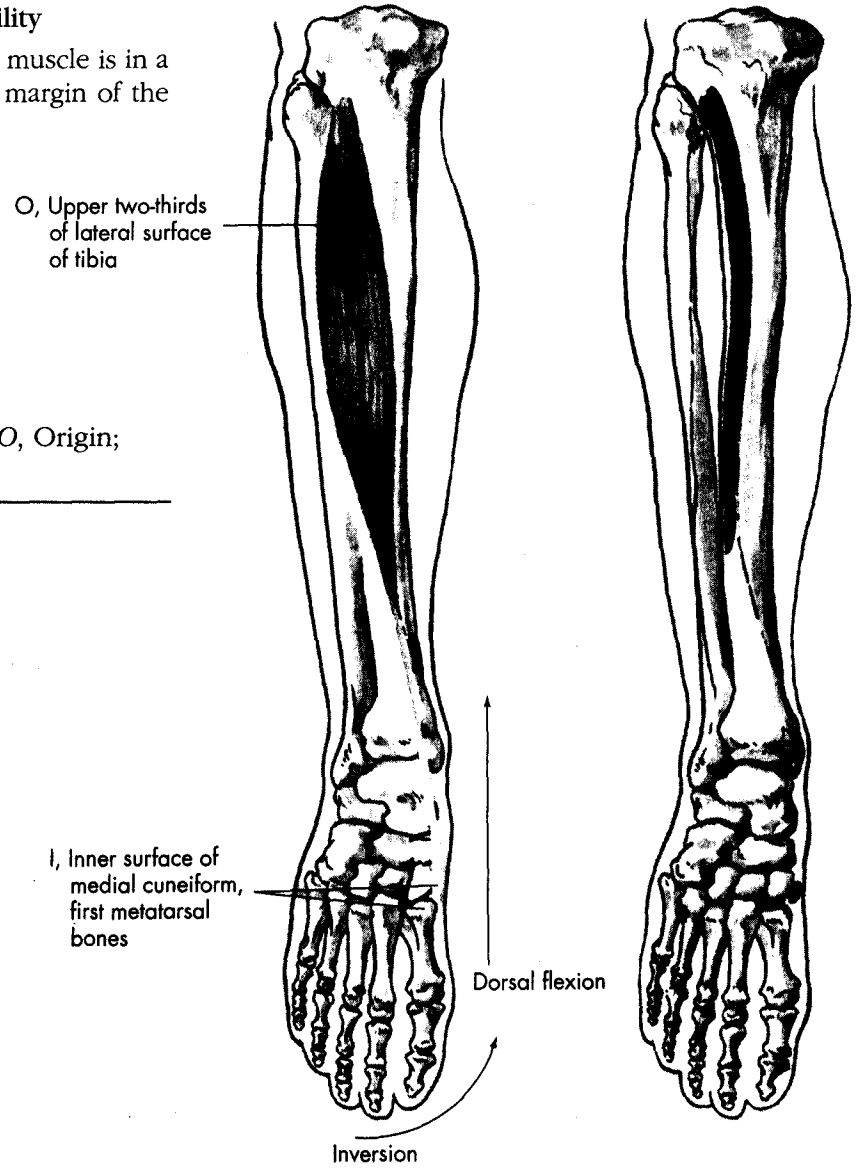


FIG. 9.15 • Tibialis anterior muscle. *O*, Origin; *I*, insertion.

Extensor digitorum longus muscle

FIG. 9.16

(eks-ten'sor dij-i-to'rum long'gus)

Origin

Lateral condyle of the tibia, head of the fibula, and upper two-thirds of the anterior surface of the fibula.

Insertion

Tops of the middle and distal phalanges of the four lesser toes.

Action

Extension of the four lesser toes.
Dorsal flexion of the ankle.
Eversion of the foot.

Palpation

Upper lateral side of the tibia; just posterolateral to the tibialis anterior.

Innervation

Deep peroneal nerve (L4-5, S1).

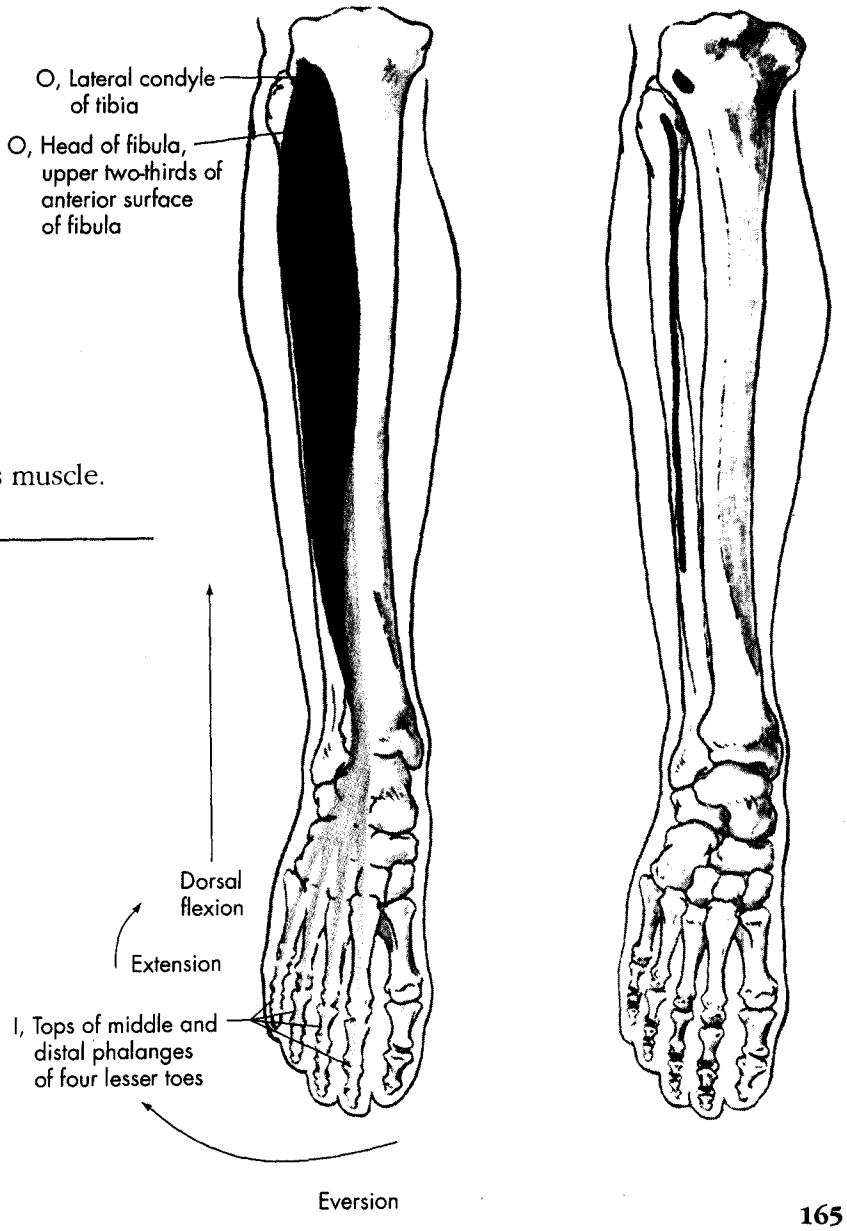


FIG. 9.16 • Extensor digitorum longus muscle. *O*, Origin; *I*, insertion.

Application, strengthening, and flexibility

Strength is necessary in the extensor digitorum longus muscle to maintain balance between the plantar and the dorsal flexors.

Action that involves dorsal flexion of the ankle and extension of the toes against resistance strengthens both the extensor digitorum longus and the extensor hallucis longus muscles. This may be accomplished by manually applying a downward force on the toes while attempting to extend them up.

The extensor digitorum longus may be stretched by passively taking the four lesser toes into full flexion while the foot is inverted and plantar flexed.

Extensor hallucis longus muscle FIG. 9.17

(eks-ten'sor hal-u'sis long'gus)

Origin

Middle two-thirds of the medial surface of the anterior fibula.

Insertion

Base of the distal phalanx of the great toe.

Action

Dorsiflexion of the ankle.
Extension of the great toe.
Weak inversion of the foot.

Palpation

Near the great toe on the dorsal surface.

Innervation

Deep peroneal nerve (L4-5, S1).

Application, strengthening, and flexibility

The three dorsiflexors of the foot—tibialis anterior, extensor digitorum longus, and extensor hallucis longus—may be exercised by attempting to walk on the heels with the ankle flexed dorsally and toes extended. Extension of the great toe, as well as ankle dorsiflexion against resistance, will provide strengthening for this muscle.

The extensor hallucis longus may be stretched by passively taking the great toe into full flexion while the foot is everted and plantar flexed.

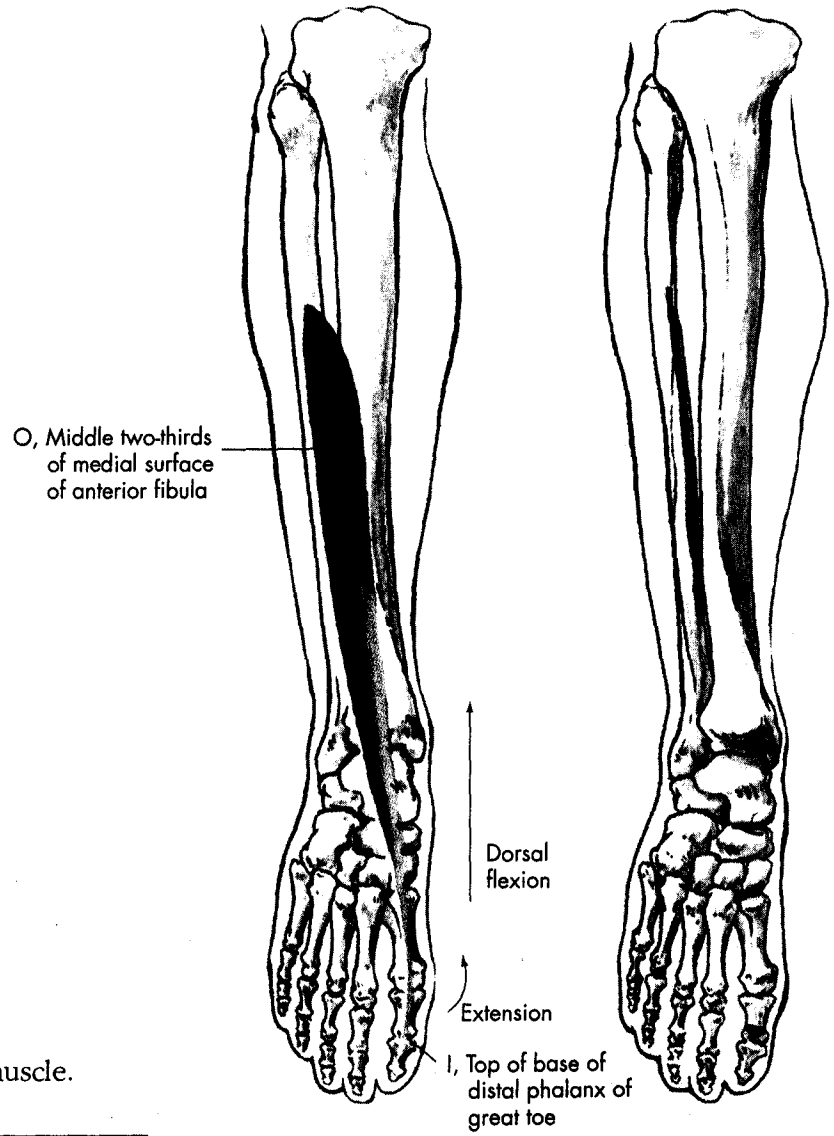


FIG. 9.17 • Extensor hallucis longus muscle. *O*, Origin; *I*, insertion.

Intrinsic muscles of the foot FIG. 9.18

The intrinsic muscles of the foot have their origins and insertions on the bones within the foot (Fig. 9.18). One of these muscles, the extensor digitorum brevis, is found on the dorsum of the foot. The remainder are found in a plantar compartment in four layers on the plantar surface of the foot. The following muscles are found in the four layers.

First (superficial) layer: Abductor hallucis, flexor digitorum brevis, abductor digiti minimi (quinti)

Second layer: Quadratus plantae, lumbricales (four)

Third layer: Flexor hallucis brevis, adductor hallucis, flexor digiti minimi (quinti) brevis

Fourth (deep) layer: Dorsal interossei (four), plantar interossei (three)

The intrinsic foot muscles may be grouped by location as well as by the parts of the foot they act. The abductor hallucis, flexor hallucis brevis, and adductor hallucis all insert either medially or laterally on the proximal phalanx of the great toe. The abductor hallucis and flexor hallucis brevis are located somewhat medially, whereas the adductor hallucis is more centrally located beneath the metatarsals.

The quadratus plantae, four lumbricales, four dorsal interossei, three plantar interossei, flexor digitorum brevis, and extensor digitorum brevis are all located somewhat centrally. All are beneath the foot except the extensor digitorum brevis, which is the only intrinsic muscle in the foot located in the dorsal compartment. Although the entire extensor digitorum brevis has its origin on the anterior and lateral calcaneus, some anatomists refer to its first tendon as the extensor hallucis brevis in order to maintain consistency in naming according to function and location.

Located laterally beneath the foot are the abductor digiti minimi and the flexor digiti minimi brevis, which both insert on the lateral aspect of the base of the proximal phalanx of the fifth phalange. Because of these two muscles' insertion and action on the fifth toe the name quinti is sometimes used instead of minimi.

Four muscles act on the great toe. The abductor hallucis is solely responsible for abduction of the great toe, but assists the flexor hallucis brevis in flexing the great toe at the metatarsophalangeal joint. The adductor hallucis is the sole adductor of the great toe, while the extensor digitorum brevis is the only intrinsic extensor of the great toe at the metatarsophalangeal joint.

The four lumbricales are flexors of the second, third, fourth, and fifth phalanges at their metatarsophalangeal joints, while the quadratus plantae are flexors of these phalanges at their distal interphalangeal joints. The three plantar interossei are adductors and flexors of the proximal phalanxes of the third, fourth, and fifth phalanges, while the four dorsal interossei are abductors and flexors of the second, third, and fourth phalanges, also at their metatarsophalangeal joints. The flexor digitorum brevis flexes the middle phalanxes of the second, third, fourth, and fifth phalanges. The extensor digitorum brevis, as previously mentioned, is an extensor of the great toe but also extends the second, third, and fourth phalanges at their metatarsophalangeal joints.

There are two muscles that act solely on the fifth toe. The proximal phalanx of the fifth phalange is abducted by the abductor digiti minimi and is flexed by the flexor digiti minimi brevis.

Refer to Table 9.1 for further details regarding the intrinsic muscles of the foot.

Muscles are developed and maintain their strength only when they are used. One factor in the great increase in weak foot conditions is the lack of exercise to develop these muscles. Walking is one of the best activities for maintaining and developing the many small muscles that help support the arch of the foot.

FIG. 9.18 • The four musculotendinous layers of the plantar aspect of the foot detailing the intrinsic muscles. **A**, Superficial layer; **B**, second layer; **C**, third layer; **D**, deep layer.

Modified from Van De Graaff KM: *Human anatomy*, ed 4, Dubuque, IA, 1995, Wm. C. Brown.

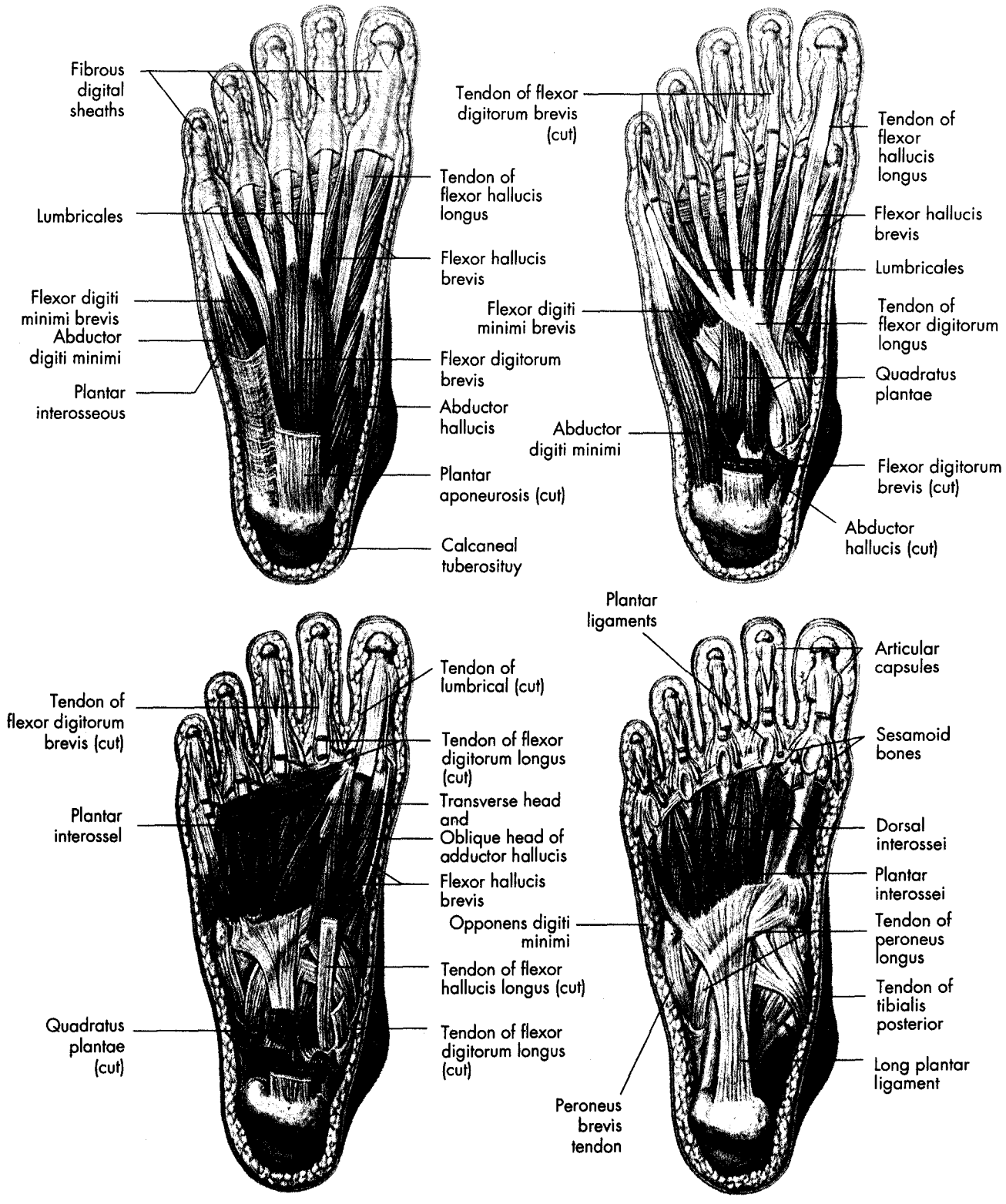


TABLE 9.1 • Intrinsic muscles of the foot

MUSCLE	ORIGIN	INSERTION	ACTION	PALPATION	INNERVATION
Abductor hallucis	Tuberosity of calcaneus, flexor retinaculum, plantar aponeurosis	Medial aspect of base of 1 st proximal phalanx	MP flexion, abduction of 1 st phalanx	Cannot be palpated	Medial plantar nerve (L4, 5)
Flexor hallucis brevis	Cuboid, lateral cuneiform	Medial head: medial aspect of 1 st proximal phalanx Lateral head: lateral aspect of 1 st proximal phalanx	MP flexion of 1 st phalange	Cannot be palpated	Medial plantar nerve (L4, 5, S1)
Adductor hallucis	Oblique head: 2nd, 3rd, and 4th metatarsals and sheath of peroneus longus tendon Transverse head: plantar metatarsophalangeal ligaments of 3rd, 4th, and 5th phalanges and transverse metatarsal ligaments	Lateral aspect of base of 1 st proximal phalanx	MP adduction of 1 st phalange	Cannot be palpated	Lateral plantar nerve (S1, 2)
Quadratus plantae	Medial head: medial surface of calcaneus Lateral head: Lateral border of inferior surface of calcaneus	Lateral margin of flexor digitorum longus tendon	DIP flexion of 2nd, 3rd, 4th, and 5th phalanges	Cannot be palpated	Lateral plantar nerve (S1, 2)
Lumbricales (4)	Tendons of flexor digitorum longus	Dorsal surface of 2nd, 3rd, 4th, and 5th proximal phalanxes	MP flexion of 2nd, 3rd, 4th, and 5th phalanges	Cannot be palpated	1st lumbricales: Medial plantar nerve (L4, 5) 2nd, 3rd, 4th lumbricales: Lateral plantar nerve (S1, 2)
Dorsal interossei (4)	Two heads on shafts of adjacent metatarsals	1st interossei: medial aspect of 2nd proximal phalanx 2nd, 3rd, and 4th interossei: lateral aspect of 2nd, 3rd, and 4th proximal phalanxes	MP abduction and flexion of 2nd, 3rd, and 4th phalanges	Cannot be palpated	Lateral plantar nerve (S1, 2)
Plantar interossei (3)	Bases and medial shafts of 3rd, 4th, and 5th metatarsals	Medial aspects of bases of 3rd, 4th, and 5th proximal phalanxes	MP adduction and flexion of 3rd, 4th, and 5th phalanges	Cannot be palpated	Lateral plantar nerve (S1, 2)
Flexor digitorum brevis	Tuberosity of calcaneus, plantar aponeurosis	Medial and lateral aspects of 2nd, 3rd, 4th, and 5th middle phalanxes	MP and PIP flexion of 2nd, 3rd, 4th, and 5th phalanges	Cannot be palpated	Medial plantar nerve (L4, 5)

Table 9.1 continued on next page

TABLE 9.1 continued • Intrinsic muscles of the foot

MUSCLE	ORIGIN	INSERTION	ACTION	PALPATION	INNERVATION
Extensor digitorum brevis	Anterior and lateral calcaneus, lateral talocalcaneal ligament, inferior extensor retinaculum	Base of proximal phalanx of 1st phalange, lateral sides of extensor digitorum longus tendons of 2nd, 3rd, and 4th phalanges	Assists in MP extension of 1st phalanx and extension of middle three phalanges	Anterior to and slightly below lateral malleolus on dorsum of foot	Deep peroneal nerve (L5-S1)
Abductor digiti minimi (quinti)	Tuberosity of calcaneus, plantar aponeurosis	Lateral aspect of 5th proximal phalanx	MP abduction of 5th phalange	Cannot be palpated	Lateral plantar nerve (S1, 2)
Flexor digiti minimi (quinti) brevis	Base of 5th metatarsal, sheath of peroneus longus tendon	Lateral aspect of base of 5th proximal phalanx	MP flexion of 5th phalange	Cannot be palpated	Lateral plantar nerve (S2, 3)

Worksheet exercise

As an aid to learning, for in-class or out-of-class assignments, or for testing, tear-out worksheets are found at the end of the text (p. 257).

Anterior and posterior skeletal worksheet (no. 1)

Draw and label on the worksheet the following muscles of the ankle and foot:

a. Tibialis anterior
b. Extensor digitorum longus
c. Peroneus longus
d. Peroneus brevis
e. Peroneus tertius
f. Soleus
g. Gastrocnemius
h. Extensor hallucis longus
i. Tibialis posterior
j. Flexor digitorum longus
k. Flexor hallucis longus

Laboratory and review exercises

1. Locate the following parts of the ankle and foot on a human skeleton and on a subject:
   a. Lateral malleolus
   b. Medial malleolus
   c. Calcaneus
   d. Navicular
   e. Three cuneiform bones
   f. Metatarsal bones
   g. Phalanges
2. How and where can the following muscles be palpated on a human subject?
   a. Tibialis anterior
   b. Extensor digitorum longus
   c. Peroneus longus
   d. Peroneus brevis
   e. Soleus
   f. Gastrocnemius
   g. Extensor hallucis longus
   h. Flexor digitorum longus
   i. Flexor hallucis longus
3. Demonstrate and palpate the following movements:
   a. Plantar flexion
   b. Dorsal flexion
   c. Inversion
   d. Eversion
   e. Flexion of the toes
   f. Extension of the toes
4. List the planes in which each of the following movements occurs. List the respective axis of rotation for each movement in each plane.
   a. Plantar flexion
   b. Dorsal flexion
   c. Inversion
   d. Eversion
   e. Flexion of the toes
   f. Extension of the toes
5. Why are "low arches" and "flat feet" not synonymous terms?
6. Discuss the value of proper footwear in various sports and activities.

7. What are orthotics and how do they function?
8. Research common foot disorders, such as flat feet, ankle injuries, and hammertoes. Report your findings in class.
9. Research the anatomical factors relating to the prevalence of inversion versus eversion ankle sprains and report your findings in class.
10. Report orally or in writing on magazine articles that rate running and walking shoes.
11. Have a laboratory partner raise up on their toes (heel raise) with their knees fully extended and then repeat with their knees flexed approximately 20 degrees. Which exercise position appears to be more difficult to maintain for an extended period of time and why? What are the implications for strengthening these muscles? For stretching these muscles?
12. In the chart below, list the muscles primarily responsible for the movements of the ankle, transverse tarsal and subtalar joint, and toes.
13. Fill in the antagonistic muscle action chart by listing the muscle(s) or parts of muscles that are antagonistic in their actions to the muscles in the left column.

Muscle analysis chart • Ankle, transverse tarsal and subtalar joint, and toes

Ankle	
Dorsiflexion	Plantar flexion
Transverse tarsal and subtalar joints	
Eversion	Inversion
Toes	
Flexion	Extension

Antagonistic muscle action chart • Ankle, transverse tarsal and subtalar joint, and toes

Agonist	Antagonist
Gastrocnemius	
Soleus	
Tibialis posterior	
Flexor digitorum longus	
Flexor hallucis longus	
Peroneus longus/ Peroneus brevis	
Peroneus tertius	
Tibialis anterior	
Extensor digitorum longus	
Extensor hallucis longus	

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