EXPERT CONTENT

Body Mechanics

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Overpronation

Pronation and supination are normal healthy motions of the foot that occur between the tarsal bones.

These motions occur primarily at the subtalar joint between the talus and calcaneus; however, they also occur at the transverse tarsal joint (the transverse tarsal joint is actually composed of two joints: the talonavicular joint medially between the talus and navicular; and the calcaneocuboid joint laterally between the calcaneus and cuboid) (Figure 1).

Pronation and supination each occur in one oblique plane around one oblique axis, therefore they are uniaxial motions; however, because these oblique plane motions occur across all three cardinal planes, pronation and supination are often described as triplanar motions.

The principle cardinal plane component motion of pronation is frontal plane eversion. For this reason, it is common to hear pronation described as eversion. However, eversion is only one component of pronation, albeit the largest. Pronation also involves subtalar abduction (effectively lateral rotation) of the foot in the transverse plane, and subtalar dorsiflexion of the foot in the sagittal plane. Similarly, the largest component motion of supination is inversion. However, supination also involves subtalar adduction (effectively medial rotation) of the foot in the transverse plane, and subtalar plantarflexion of the foot in the sagittal plane.

Foot pronation causes the arch structure of the foot to drop. The arch structure consists of three arches: the medial longitudinal arch on the big toe side, which is the largest and best known of the arches; the lateral longitudinal arch on the little toe side; and the transverse arch across the metatarsal heads (Figure 2). Whenever any one of these arches collapses, as a rule, the entire arch structure collapses.

OVERPRONATION/FLAT FOOT

Dropping the arch structure of the foot is a natural and healthy posture. It occurs during the gait cycle during midstance when our body weight is directly above the foot. Before much of our world was paved and flat, the ground was often uneven. From a position of full supination, varying the degree of pronation would therefore allow the arch to drop and flatten the necessary amount to mold to the contour of the ground upon which we are standing (Figure 3). Pronating to drop the arch also allows for shock absorption when striking the ground during walking, running, and jumping. The problem is when our arch structure excessively pronates, in other words, overpronates.

Because overpronation causes the arch structure to drop, it is known in lay terms as *flat foot*. In scientific terms, it is known as *pes planus*, which is Latin for "foot flat" (pes cavus is the term for an overly supinated foot, in other words, an excessively high arch). There are two types of overpronation/flat foot: rigid flat foot and supple flat foot. With supple flat foot, which is the more common of the two types, the client's arch is perfectly healthy when not weight-bearing, but upon weight-bearing, the foot pronates excessively and the arch structure collapses. By contrast, a rigid flat foot is always flat/overly pronated, regardless of whether the client is weight-bearing or not (Figure 4).

CAUSES

There are many causes of supple flat foot. Given that the arch structure of the foot is determined by soft tissue pulls of musculature and ligaments, a supple flat foot is caused by either lax ligaments and/or weak musculature that cannot support the arch when the weight of the body passes through the subtalar (and transverse tarsal) joint. Muscles that act to support the arch can be divided into the following groups (Table 1):

Supinators (invertors) of the foot – These muscles have their bellies located in the leg. They are the tibialis anterior and the extensor hallucis longus in the anterior

Foot pronation causes the arch structure of the foot to drop.

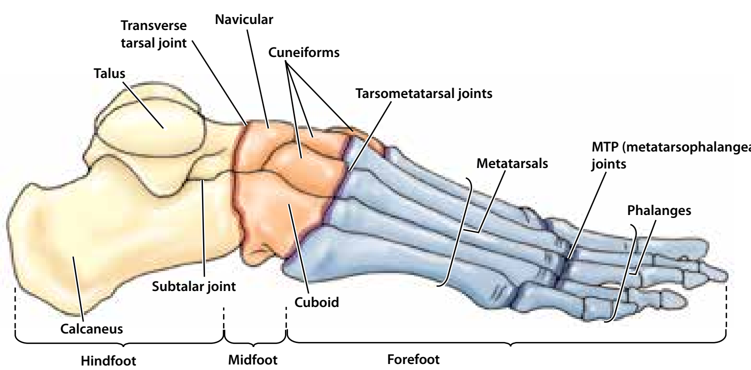


Figure 1 The subtalar joint of the foot. The transverse tarsal joint is also seen. *Muscolino, JE. Kinesiology: The Skeletal System and Muscle Function. 2ed. Elsevier.*

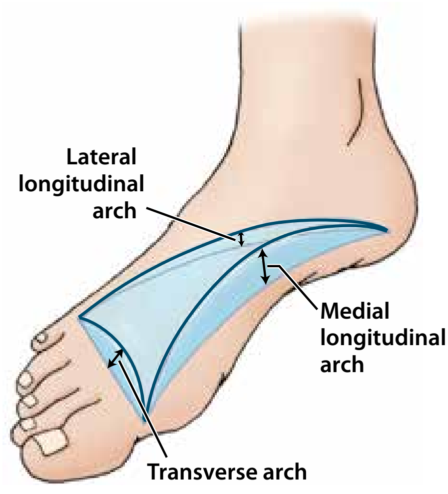


Figure 2 The Arch structure of the foot is composed of the medial longitudinal arch, the lateral longitudinal arch, and the transverse arch. *Muscolino, JE. Kinesiology: The Skeletal System and Muscle Function. 2ed. Elsevier.*

Figure 3 Varying the degree of supination/pronation allows the foot to mold to the contour of the ground. *(Modeled from a figure in Neumann, DA: Kinesiology of the musculoskeletal system: foundations for physical rehabilitation, ed 2, St. Louis, 2010, Elsevier.)*

Figure 4 Overpronation of the foot, also known as flat foot. A, Supple flat foot when not weight-bearing. B, The same supple flat foot when weight-bearing. C, Rigid flat foot. Note: The contour of the medial longitudinal arch is highlighted in each figure. *Courtesy Joseph E. Muscolino DC*

Table 1 Musculature that supports the arch

LEG/SUBTALAR JOINT	FOOT/PLANTAR FASCIA	THIGH/HIP JOINT
Tibialis anterior		Gluteus maximus
Extensor hallucis longus		Gluteus medius and minimus
Tibialis posterior	Flexor digitorum brevis	Piriformis
Flexor digitorum longus	Abductor hallucis	Quadratus femoris
Flexor hallucis longus	Abductor digiti minimi pedis	Superior and inferior gemellus
Fibularis longus		Obturator internus and externus
		Sartorius
		Tensor fasciae latae (TFL)

compartment; and the *Tom, Dick and Harry group*: tibialis posterior, flexor digitorum longus, and flexor hallucis longus muscles of the posterior deep compartment (Figures 5A and 5B).

"Stirrup Muscles" —The stirrup muscles, whose bellies are also located in the leg, are named because they support the arch/underside of the foot like a stirrup. They are the tibialis anterior of the anterior compartment (already mentioned above) and the fibularis longus of the lateral compartment (see Figure 5A).

Intrinsic plantar musculature—Muscles of Plantar Layer I group of the intrinsic plantar musculature have attachments into the plantar fascia. By supporting the plantar fascia, they help to support the arch (see Figure 5C). They are the flexor digitorum brevis, abductor hallucis, and abductor digiti minimi pedis.

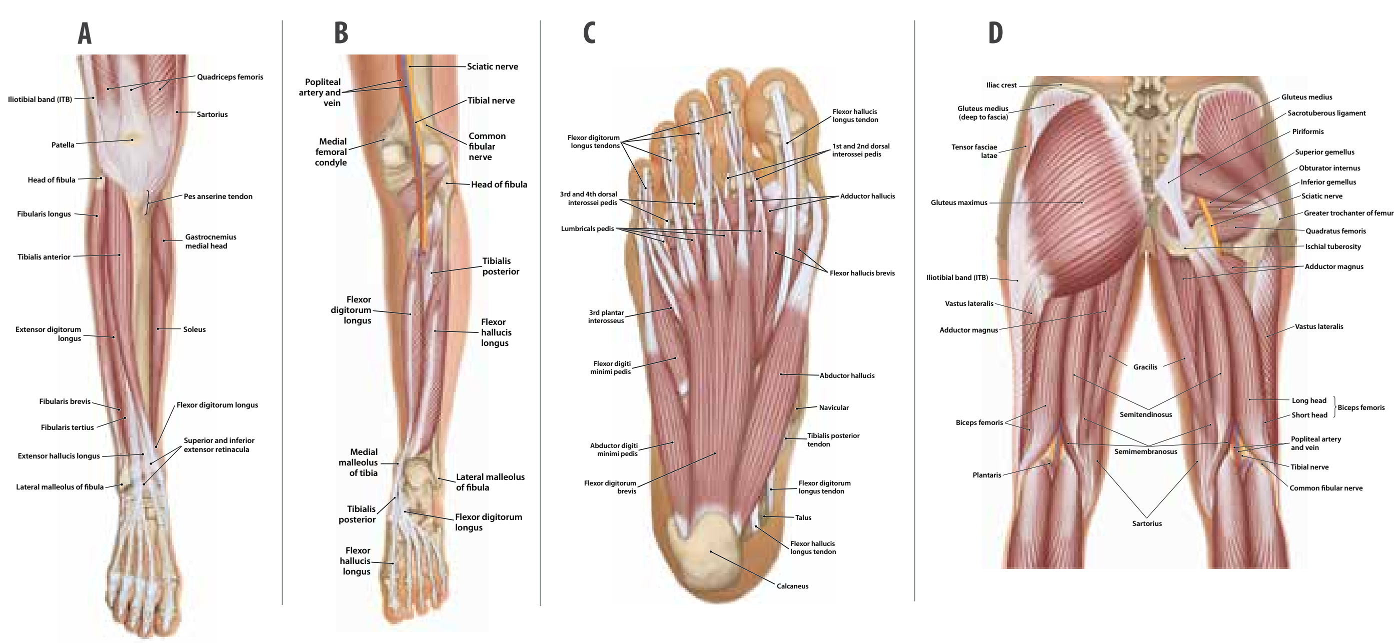
Lateral rotators of the thigh at the hip joint—This group indirectly supports the arch because it acts to prevent the thigh from medially rotating. When the weight-bearing foot pronates, because the foot is planted on the ground, the calcaneus of the subtalar joint is not fully free to move, therefore the talus moves as well. This is a closed-chain reverse action of the proximal talus upon the distal calcaneus, and results in medial rotation of the talus. Because the ankle (talocrural) joint does not allow rotation, the tibia medially rotates with the talus; and because the extended knee joint also does not allow rotation, the femur medially rotates with the tibia. Therefore, hip joint lateral rotation musculature can support the arch by acting to brake/prevent medial rotation of the femur/tibia/talus. Hip joint lateral rotation musculature includes the posterior gluteal musculature, the deep lateral rotator group (piriformis, quadratus femoris, superior and inferior gemellus, and obturator internus and externus), and the sartorius. (Figure 5D)

It should be mentioned that hip joint abductor musculature can also be important for maintaining the arch of the foot. If this musculature is weak, the thigh can fall into adduction, this causes a genu valgus force (abduction of the leg at the knee joint), which tends to result in medial rotation of the thigh, and therefore the leg and talus, promoting arch collapse. Abductors of the hip joint are the gluteal muscles, tensor fasciae latae (TFL), and the sartorius.

Another contributor to overpronation is tight pronator (evertor) musculature (fibularis musculature and extensor digitorum longus), which can pull the foot into pronation on that side, making it more difficult for the supinator musculature to support the arch structure.

Most all fascial ligamentous tissue that is located on the plantar side of the foot helps to support the arch. Most notable are the long and short plantar ligaments, the spring ligament, the intertransverse metatarsal

Figure 5 Muscles that support the arch. A, Superficial view of the anterior leg. B, Deep view of the posterior leg. C, Superficial view of the plantar foot. D, Deep view of the posterior pelvis. *Muscolino, JE. Kinesiology: The Muscular System Manual: The Skeletal Muscles of the Human Body, 3ed. Elsevier.*



ligaments, and the plantar fascia (Figure 6). If this fascial ligamentous tissue is excessively lax, perhaps due to genetic factors or to forces placed upon it during life, it will not be able to hold the bones in their proper posture, especially during weight-bearing postures, and the arch will collapse.

As stated, the collapsed arch of overpronation essentially occurs because of the inability of the musculature and ligament complex to support the arch structure, especially when bearing weight. Therefore, any factor that increases downward force through the arches will tend to exacerbate this condition. First among these factors is being overweight, which increases the weight that is borne through the arches. Carrying heavy loads/objects acts in a similar manner because the weight of whatever is being carried must ultimately pass through the arches of the feet.

Another factor is a turned out posture of the foot. This usually occurs because of excessively tight baseline tone of deep lateral rotation musculature of the thigh at the hip joint (e.g., piriformis). When walking with a turned out posture, the person's weight passes more directly over the medial longitudinal arch, increasing the likelihood that it will collapse (Figure 7). Ironically, the baseline tone of the lateral rotation musculature of the hip joint might be tight enough to cause the unhealthy turned out posture of the foot, but not strong enough to prevent the weight-bearing foot from overly pronating as a result of this altered posture. It is important for the lateral rotation musculature to have a healthy and loose baseline tone, but to be strong enough to contract to prevent overpronation when needed during the gait cycle.

Proper footwear can be another factor. If a person does overly pronate, then wearing shoes that have little or no arch support can allow the excessive pronation to occur. Wearing high-heeled shoes can also exacerbate this problem because they shift body weight to be borne more anteriorly in the foot, increasing force through the transverse arch, causing it to collapse. This will result in weakness of the entire arch structure of the foot, including the medial and lateral longitudinal arches, thereby resulting in overpronation.

> There are two types of overpronation/flat foot: rigid flat foot and supple flat foot.

Figure 6 Fascial ligamentous tissues on the plantar surface of the foot that help to support the arch. Medial view. Note: The intertransverse metatarsal ligaments are not seen.

Figure 7 Walking with the foot turned out increases weight-bearing force directly over the medial longitudinal arch of the foot, increasing the likelihood that the foot will overly pronate. *Courtesy Joseph E. Muscolino DC*