AN OVERVIEW ABOUT ANATOMY OF SKELETAL MUSCLES

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Abstract

Background: The musculoskeletal system comprises one of the major tissue/organ systems in the body. The three main types of muscle tissue are skeletal, cardiac, and smooth muscle groups. Skeletal muscle attaches to the bone by tendons, and together they produce all the movements of the body. The skeletal muscle fibers are crossed with a regular pattern of fine red and white lines, giving the muscle a distinctive striated appearance. Hence they are also known as striated muscles. Skeletal muscle function is to produce movement, by pulling on the skeletal frame of the body, to maintain posture and to protect the underlying structures, particularly in areas lacking skeletal protection. In addition, muscular contraction causes thermogenesis and acts as a vascular pump. Lymph capillaries originate in skeletal muscle in the microvascular unit within the endomysium near the main capillary bed and drain the tissue fluid. These capillaries merge to form the lymphatic vessels as they drain out the tissue fluid. These lymphatic vessels go through the perimysium and join with the larger lymphatic vessels. Gastrocnemius is a large muscle located in the posterior leg. Posteriorly, is the most superficial of the muscles of the leg, and forms the bulk of the calf. It takes its name from the Greek words γαστήρ (gaster) meaning stomach or belly, and κνήμη (kneme) meaning leg; the combination of the two words means the "belly of the leg" or in other words the bulk of the calf. In conjunction with the soleus muscle, it is a component of a composite, three-headed group of muscles referred to as triceps surae. The triceps surae is a musculotendinous complex involved in balance and walking. It is a heavily used muscle in athletes. The complexity of its architecture is linked to its fundamental role during the various phases of walking and running. The Achilles tendon, named after the mythical hero of Homer's the Iliad, is the strongest tendon in the human body. The Achilles tendon sees the highest loads in the body, experiencing up to 10 times body weight during running, skipping, and jumping.

Keywords: Skeletal Muscles, Anatomy

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Introduction

The musculoskeletal system comprises one of the major tissue/organ systems in the body. The three main types of muscle tissue are skeletal, cardiac, and smooth muscle groups. Skeletal muscle attaches to the bone by tendons, and together they produce all the movements of the body. The skeletal muscle fibers are crossed with a regular pattern of fine red and white lines, giving the muscle a distinctive striated appearance. Hence they are also known as striated muscles ***(1)***

Skeletal muscle function is to produce movement, by pulling on the skeletal frame of the body, to maintain posture and to protect the underlying structures, particularly in areas lacking skeletal protection. In addition, muscular contraction causes thermogenesis and acts as a vascular pump ***(2)***.

Organization of the skeletal muscle

A skeletal muscle can contain hundreds of thousands of muscle fibers as well as blood vessels and nerves. Throughout the muscle, providing internal structure and scaffolding, is an extensive network of connective tissue. The entire muscle is covered in a connective tissue sheath called the epimysium ***(3)***.

Within the muscle the cells are collected into separate bundles called fascicles, and each fascicle is covered in its own connective tissue sheath called the perimysium. Within the fascicles the individual muscle cells are each wrapped in a fine connective tissue layer called the endomysium. Each of these connective tissue layers runs the length of the muscle. They bind the fibers into a highly organized structure and blend together at each end of the muscle to form the tendon, which secures the muscle to bone ***(4)***.

Often the tendon is rope-like but sometimes it forms a broad sheet called an aponeurosis, e.g. the occipitofrontalis muscle. The multiple connective tissue layers throughout the muscle are important for transmitting the force of contraction from each individual muscle cell to its points of attachment to the skeleton. The fleshy part of the muscle is called the belly ***(5)***.

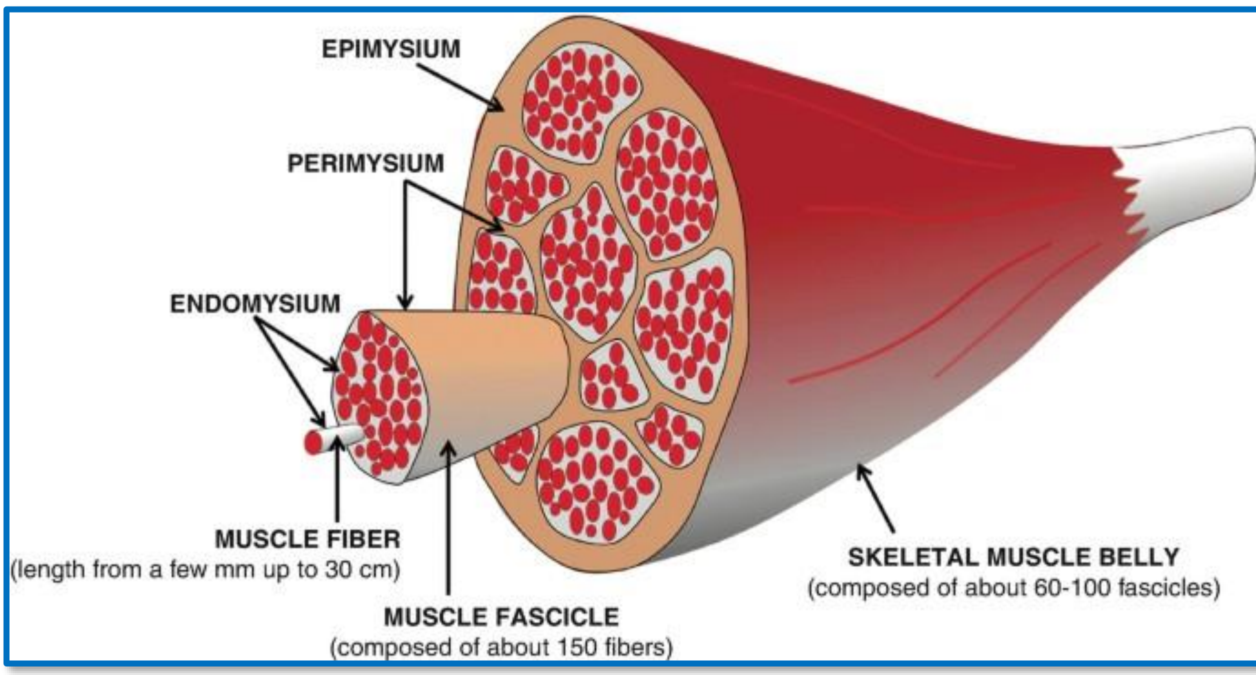

Fig. 1: Schematic drawing of the gross organization of skeletal muscle ***(6)***.

Classification

(1) Number of points of origin

A muscle group may be composed of several independent muscles, called “muscle heads”. These are named according to the number of muscles involved; examples include the biceps (“two heads”), triceps (“three heads”) and quadriceps (“four heads”) which are composed, respectively, of 2, 3 and 4 muscles with different origins that converge on a common tendon ***(7)***.

(2) Fiber shape and arrangement:

Based on the shape and arrangement of fibers, skeletal muscles can be broadly classified into four major anatomical types ***(8)***:

- **Parallel Muscles**

Here, the orientation of the muscle fibers within the fascicles is parallel to one another. Together, their gross shape can vary from flat to fusiform. The flat muscles usually have a uniform surface, while the fusiform muscles have a protrusion in the middle referred to as the belly. The majority of the skeletal muscles of our body are parallel. One of the best examples of a fusiform muscle is biceps brachii ***(9)***.

- **Pennate Muscles**

If a tendon runs along the entire length of a muscle and the muscle fibers fan out from the tendon, the muscle is said to be pennate. The pennate muscles are further subdivided into three types ***(6)***.

(a) Unipennate (b) Bipennate (c) Multipennate

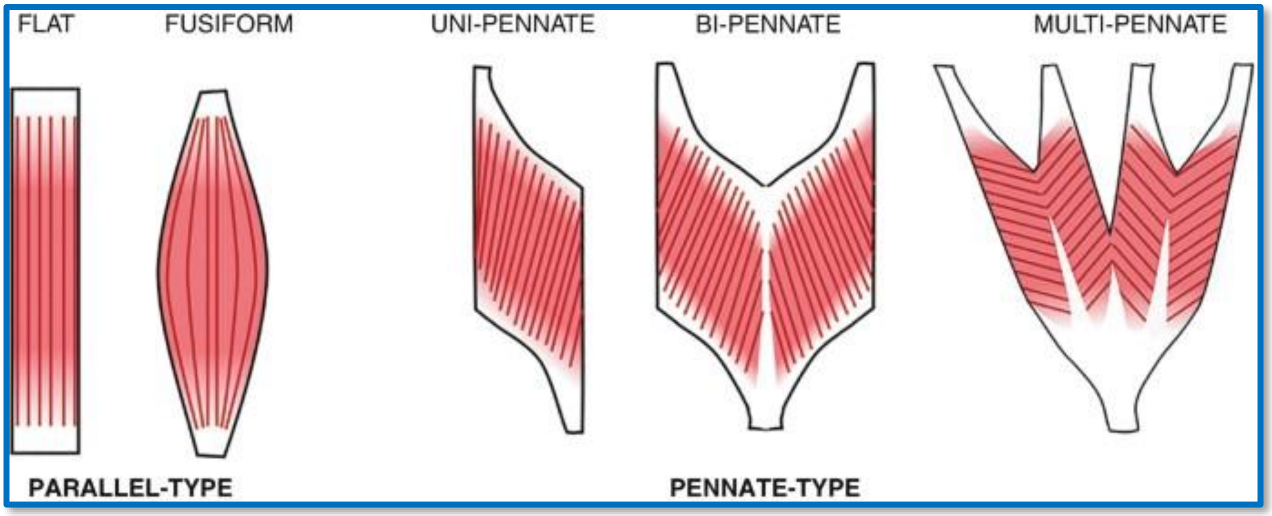

Fig. 2: Diagrammatic illustration of parallel and pennate skeletal muscles ***(6)***.

- **Convergent Muscles**

All the muscle fibers fan out from a single origin of attachment. Pectoralis major is a convergent muscle ***(10)***.

- **Circular Muscles**

As the name suggests, the muscle fibers are arranged circumferentially. The fascicles are not necessarily associated with a tendon. Orbicularis oculi is a circular muscle ***(9)***.

(3) Mode of action

On the base of functional criteria, muscles may be classified as flexors or extensors, abductors or adductors, pronators or supinators and internal or external rotators, depending on the movement generated by contraction. The names of many forearm and leg muscles begin with extensor or flexor, indicating how they move the hand, foot and digits ***(11)***.

(4) Number of articulations involved

On the basis of the insertion point of the muscle to the skeleton, and how many articulations are involved, a muscle may be classified as mono-, bi- or polyarticular. Monoarticular muscles bridge one joint and join two bones; thus, movement is confined to one joint, e.g. the coracobrachialis muscle ***(7)***.

Biarticular muscles span two joints; often these muscles have two or more tendons at one extremity and one tendon at the other end; one tendon is monoarticular, while the other is biarticular. Polyarticular muscles span more than two joints, with tendon insertions on several bone sites; these include very long muscles, usually located along the spinal column, that make contact with each vertebra ***(12)***.

Blood supply

The main artery or the primary artery supplying blood to the skeletal muscle courses parallel to the longitudinal axis of the muscle fiber. The primary artery gives off tributaries known as feed arteries. The feed artery branches into primary arterioles, which after two more orders of branching, gives rise to transverse arterioles, which in turn give rise to terminal arterioles. The terminal arterioles are the final vascular branches, and they perfuse the capillaries that are present within the endomysium and travel parallel to the longitudinal axis of the muscle fiber ***(13)***.

The terminal arteriole, along with the capillaries that it supplies, is known as a microvascular unit. It is the smallest unit in the entire skeletal muscle where the blood flow can be regulated ***(9)***.

Lymphatic drainage

Lymph capillaries originate in skeletal muscle in the microvascular unit within the endomysium near the main capillary bed and drain the tissue fluid. These capillaries merge to form the lymphatic vessels as they drain out the tissue fluid. These lymphatic vessels go through the perimysium and join with the larger lymphatic vessels ***(13)***.

Unlike the blood vessels, the wall of the lymph vessels within the muscle does not have contractile property due to a lack of smooth muscles(in the wall), so they depend on the muscle movement and arteriolar pulsations to drain the lymph out ***(14)***.

Nerve supply

The neuronal innervation of a skeletal muscle typically comprises sensory nerve fibers, motor nerve fibers, and the neuromuscular junction. The nerve fibers are composed of myelinated as well as non-myelinated nerve fibers. The cell bodies of the neurons give rise to large axons, which are generally unbranched and travel to the target muscles for innervation ***(13)***.

Gastrocnemius Muscle

Gastrocnemius is a large muscle located in the posterior leg. Posteriorly, is the most superficial of the muscles of the leg, and forms the bulk of the calf. It takes its name from the Greek words *γαστήρ* (gaster) meaning stomach or belly, and *κνήμη* (kneme) meaning leg; the combination of the two words means the "belly of the leg" or in other words the bulk of the calf. In conjunction with the soleus muscle, it is a component of a composite, three-headed group of muscles referred to as triceps surae. The triceps surae is a musculotendinous complex involved in balance and walking. It is a heavily used muscle in athletes. The complexity of its architecture is linked to its fundamental role during the various phases of walking and running ***(15)***.

Anatomy

The triceps surae muscle-tendon complex is innervated by the tibial nerve. The gastrocnemius muscle is composed of two independent heads, the medial head and lateral head. The gastrocnemius muscle is a bi-articular muscle and morphologically defined as pennate ***(16)***.

Attachment

It arises by two heads, connected to the condyles of the femur by strong, flat tendons. The medial, larger head is attached to a depression at the upper and posterior part of the medial condyle behind the adductor tubercle, and to a slightly raised area on the popliteal surface of the femur just above the medial condyle. The lateral head is attached to a recognizable area on the lateral surface of the lateral condyle and to the lower part of the corresponding supracondylar line. Both heads also arise from subjacent areas of the capsule of the knee joint. The tendinous attachments expand to cover the posterior surface of each head with an aponeurosis, from the anterior surface of which the muscle fibers arise. The fleshy part of the muscle extends to about mid-calf. The muscle fibers of the larger medial head extend lower than those of the lateral head. As the muscle descends, the muscle fibers begin to insert into a broad aponeurosis that develops on its anterior surface; up to this point, the muscular masses of the two heads remain separate. The aponeurosis gradually narrows and receives the tendon of soleus on its deep surface to form a large tendon called the calcaneal (Achilles) tendon. The calcaneal tendon attaches to the posterior surface of the calcaneus in the foot ***(17)***.

The medial head is generally thicker and wider than the lateral head. At the medial condyle of the femur/origin of the medial head, there is a serous bursa, which allows the proximal muscular body of the lateral head of the muscle to slide. This bursa comes in contact with the bursa of the semimembranosus muscle, creating a functional link of continuity. The bursa involving the medial head may be the site of Baker's cyst.In 10% to 30% of the population, the tendon of the lateral head frequently contains a sesamoid bone, the fabella, where it moves over the lateral femoral condyle. It may occasionally occur in the tendon of the medial head. It could play a role in stabilizing the knee.***(18)***.

Fig. 3: Posterior view of the right leg shows the lateral gastrocnemius muscle (1), the medial gastrocnemius muscle (2), the soleus muscle (3), the calcaneal tendon (4), the fibularis brevis muscle (5) and the flexor hallucis longus muscle (6) ***(15)***.

Anatomical relations

Proximally, the lateral and medial heads of gastrocnemius form the inferior boundaries of the popliteal fossa. The tendon of biceps femoris partially covers the lateral head, and semimembranosus partially covers the medial head. For the remainder of its length, the muscle is superficial, with both bellies visible beneath the skin. The small saphenous vein and accompanying sural nerve run along the superficial surface of the muscle, separated from it by the deep fascia. The common fibular nerve crosses the lateral head of the muscle, between it and biceps femoris. Deep to gastrocnemius are the soleus, popliteus and plantaris muscles, the popliteal vessels and the tibial nerve. The deep flexor muscles, flexor digitorum longus, flexor hallucis longus and tibialis posterior, also lie deep to gastrocnemius ***(17)***.

Function

Along with the soleus muscle, the gastrocnemius forms half of the calf muscle. Its function is plantar flexing the foot at the ankle joint and flexing the leg at the knee joint. The gastrocnemius is primarily involved in running, jumping and other "fast" movements of leg, and to a lesser degree in walking and standing. This specialization is connected to the predominance of white muscle fibers (type II fast twitch) present in the gastrocnemius, as opposed to the soleus, which has more red muscle fibers (type I slow twitch) and is the primary active muscle when standing still, as determined by EMG studies ***(19)***.

Variants

On occasion, the lateral head, or the whole muscle, is absent. A third head arising from the popliteal surface of the femur is sometimes present. Also, it is possible to find a quadriceps gastrocnemius muscle. Practitioners do not know if this variant causes dysfunctions and pathologies; the tibial nerve innervates this variant ***(20)***.

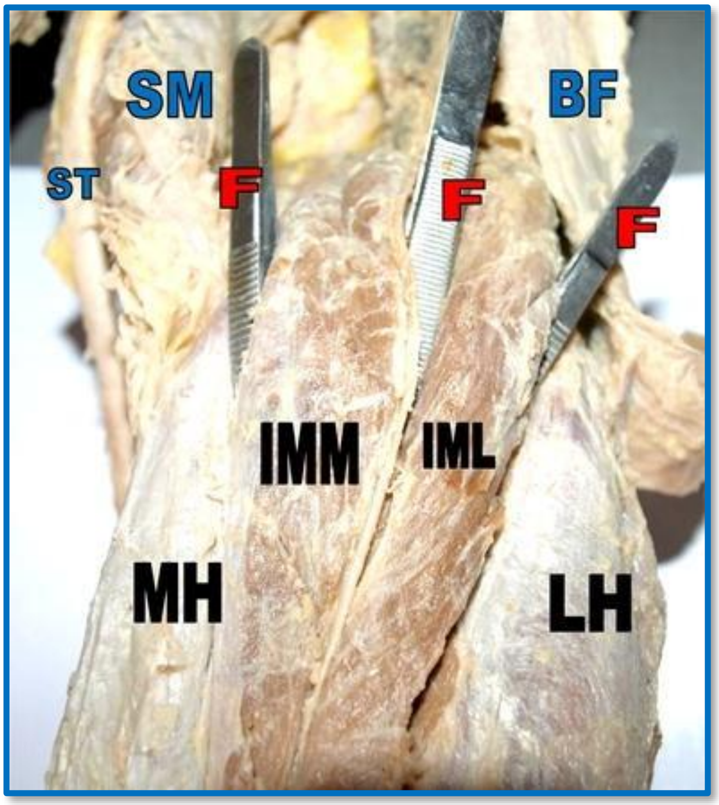

Fig. 4: Popliteal region showing four-headed gastrocnemius muscle on the right leg. MH medial head, IMM intermedio-medial head, IML intermedio-lateral head, LH lateral head, ST semitendinosus, SM semimembranosus, BF biceps femoris, F forceps ***(20)***

<u>Blood supply</u>

Both medial and lateral heads of gastrocnemius are supplied by the lateral and medial sural arteries, these arteries are branches of the popliteal artery and arise at variable levels, usually at the level of the tibiofemoral joint line. The medial sural artery almost always arises more proximally and the lateral more distally. Minor accessory sural arteries may also branch off the popliteal and superior genicular arteries. ***(21)***.

Venous drainage is through corresponding medial and lateral sural veins into the popliteal vein. The popliteal vein drains the venous blood from the gastrocnemius muscle. The popliteal vein is formed by the junction of the saphenous vein, posterior tibial veins, and anterior tibial veins on the lower edge of the popliteal muscle and the medial side of the popliteal artery. Ascending, it passes through the opening of the adductor to become the femoral vein. The perforating veins that influence blood flow during calf contraction are called Cockett veins ***(22)***.

Nerves

The gastrocnemius is innervated by the anterior rami of S1 and S2 spinal nerves, carried by the tibial nerve into the posterior compartment of the leg. The tibial branch and a peroneal branch, these two nerves constitute the main trunk of the sciatic nerve; they are separated inside the sciatic by a fascial/adipose tissue or septum, known as the septum of Compton-Cruveilhier. The tibial nerve is the larger terminal branch of the sciatic nerve in the lower third of the back of the thigh. It descends through the popliteal fossa and passes deep to the gastrocnemius and soleus muscles. It lies on the posterior surface of the tibialis posterior and, lower down the leg, on the posterior surface of the tibia. The nerve accompanies the posterior tibial artery and lies at first on its medial side, then crosses posterior to it, and finally lies on its lateral side. The nerve, with the artery, passes behind the medial malleolus, between the tendons of the flexor digitorum longus and the flexor hallucis longus. It is covered here by the flexor retinaculum and divides into the medial and lateral plantar nerves **(23).**

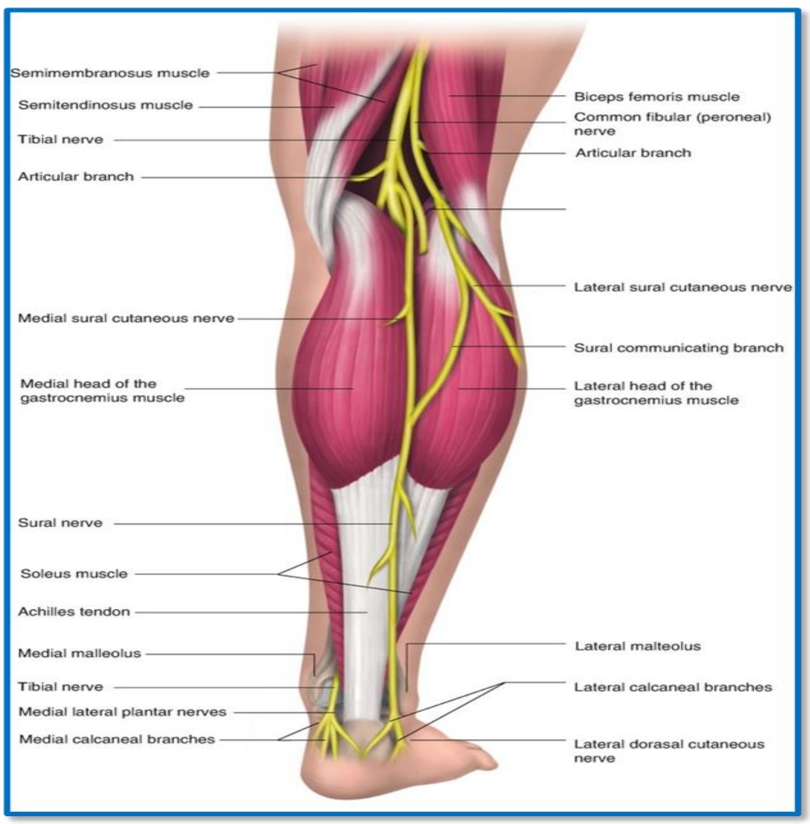

Fig. 5: Anatomy of the posterior lower leg including the calf muscles and Achilles tendon ***(24)***.

<u>Tendon Achilles</u>

The Achilles tendon, named after the mythical hero of Homer's the Iliad, is the strongest tendon in the human body. The Achilles tendon sees the highest loads in the body, experiencing up to 10 times body weight during running, skipping, and jumping ***(25)***.

The Achilles tendon is the conjoint tendon of the medial and lateral gastrocnemius muscles as well as the soleus. A raphe forms where the two heads of the gastrocnemius join, which continues distally to join the soleus ***(26)***.

Variable contributions from the gastrocnemius and soleus exist in the Achilles tendon. Variable lengths of tendon contributions exist, between 3 and 11 cm from the soleus and between 11 and 16 cm from the gastrocnemius ***(25)***.

Insertional anatomy

The Achilles tendon spirals as it courses distally toward its calcaneal insertion, twisting from medial to posterior to lateral, allowing stored elastic energy to be expended during the appropriate phase of gait or movement ***(27)***.

No synovial sheath exists around the Achilles tendon; rather, the paratenon, which is a thin layer of areolar tissue, allows gliding of the tendon within its sheath. Composed of mucopolysaccharides, the paratenon blends proximally with the fascia of muscle and distally with the periosteum of the calcaneus ***(25)***.

Anatomical regions

Simply, the tendon can be divided into insertional (distal) and noninsertional (proximal) components. Additional classification systems have been proposed to stratify areas of the tendon into 3 regions: the insertional calcaneal region, the preinsertional region located 2 cm proximal to the calcaneal insertion, and the noninsertional, midportion of the tendon ***(28)***.

Size and length

Based on cadaveric and radiologic studies, the average length of the Achilles tendon is 15 cm. The width of the Achilles tendon varies considerably throughout its length. It is widest proximally, measuring an average of 6.8 cm wide. The tendon reaches its narrowest diameter about 80% of the distance down the length of the tendon before widening again at its calcaneal insertion to 3.4 cm. At its narrowest point, the tendon averages only 1.8 cm in width ***(29)***.

Relations

The calcaneal tendon is subcutaneous. The sural nerve crosses its lateral border about 10 cm above its insertion; the nerve is especially vulnerable here to iatrogenic injury during surgery. Distally, there are bursae superficial and deep to the tendon. The muscle belly of flexor hallucis longus lies deep to the deep fascia on the anterior surface of the tendon. ***(29)***.

Blood supply

The blood supply of the Achilles tendon consists mainly of longitudinal arteries that course the length of the tendon. Two main blood vessels supply the tendon. The posterior tibial artery supplies both the proximal and distal sections. The peroneal artery supplies the middle section. Overall, the tendon has a relatively poor blood supply throughout its length, as measured by vessels per cross-sectional area. Also, there is a relatively hypovascular area in the midsection, which correlates to the location of many injuries: the area approximately 2 to 6 cm from the tendon's insertion point. Some have also suggested that poor vascularity contributes to diminished healing after trauma. Blood supply to the tendon also diminishes with age ***(30)***.

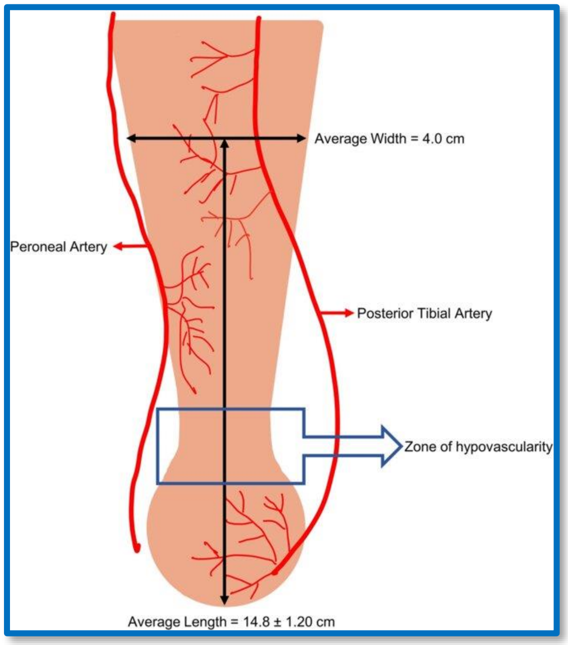

Fig. 6: Blood supply of tendon Achilles ***(30)***.

Nerve supply

The Achilles tendon is innervated mainly by the sural nerve (sensory contribution), with minor contributions from other smaller branches of the tibial nerve. Testing of the Achilles deep tendon reflex is common and involves bluntly hitting the tendon, ordinarily causing plantar flexion of the foot. This test assesses the sacral nerve roots S1 and S2 ***(25)***.

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